Information Encoding: Importance of Attention in Change Blindness Task

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A Thesis Submitted in Partial Fulfilment

of the Requirements for the Degree of

Master of Philosophy

in

Psychology

June 2006

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摘要

心理學家任昇(R. Rensink,2000b)從改變盲(change blindness)的研究中提出了「統一理論」(coherence theory)，指出觀察者不能保留前改變圖象(pre-change scene)的訊息。這跟霍林沃思及亨德森(Hollingworth & Henderson, 2002)建議的視覺記憶理論(visual memory theory)有所分異。在他們的理論中，觀察者是可以記起曾處理的訊息。不過，由於兩個理論在使用的實驗設計上有不同，所以結果不能直接比較。這篇論文的研究目的是理解已處理的前改變圖象的訊息的穩定性。當中包括三種變更: 刪減(deletion)、表徵上的變動(token change)、和物種上的變動(type change)。再加上實驗過程中對注意力分配的控制: 供提示、不供提示。結果反映出在任何一種變更及注意力分配的情形下，觀察者能分別開前改變圖象及後改變圖象(post-change scene)的訊息。

另外，依據奧里根(O'Regan,2001)所提出的「哪裏」及「什麼」任務("where" and "what" task)的分別，除了傳統的定位任務(localization task)外，被試(subject)亦要選出被改變物件的名稱(object naming)、及顏色(color labeling)。在定位任務中，被試的表演跟以往的文獻近似。而在「什麼」任務中，被試在兩項任務的表演會受不同的變更影響。這支持了奧里根的論點: 用「哪裏」任務來推論觀察者對物件的記憶並不是理想的方法。

Abstract

The coherence theory (Rensink, 2000b) from change blindness (CB) studies suggested that observers do not maintain encoded information from the pre-change scene. It contradicts with the visual memory theory (Hollingworth & Henderson, 2002), which provided evidence that observers were able to retrieve the encoded information. However, the two theories cannot be compared directly due to the un-standardized experimental paradigm. In this thesis, the stability of encoded pre-change information is investigated. Three types of change were included, deletion, token and type changes, and attentional allocation was manipulated by a cued and an un-cued condition. Evidence showed that in spite of the kinds of changes and attentional allocation condition, observers maintain the pre-change information and they are able to separate the memory of the pre-change object from the post-change one.

In addition, apart from the traditional localization task, i.e. the "where" task, two "what" task (O'Regan, 2001) which is consisted of an object naming task and a color labeling task of the pre-change object is included. Performance for localization task agrees with previous CB studies. Result reveals that the "what" tasks interacted with kinds of change. It supports that drawing inference for the "what" information based on a "where" task would not be an ideal approach (O'Regan, 2001).

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Brief Summary in Change Blindness Studies

"Change detection is the apprehension of change in the world around us" (Rensink, 2002). From daily life experience, it seems that we are aware of all stimuli present. For example, when we are typing, we notice pens and books on our desk. It seems that we can handle many visual inputs and obtain details of objects. Sometimes, however, we are over-optimistic towards the information we have (Levin, Drivdahl, Momen, 2002).

Change blindness (CB), is the phenomenon that we may miss a change that happens in front of us. There are findings in both the laboratory settings, (e.g. Hollingworth, Schrock, & Henderson, 2001; Mondy & Coltheart, 2000) as well as in the real world (e.g. Simons, & Levin, 1998; Simons, Chabris, & Schnur, 2002). In a typical laboratory CB paradigm, subjects look for a change happens while two highly similar scenes are replacing each other separated by a visual disruption (e.g. blank screen or mask) that the detection rate is usually low. Participants seem "blind" to the change. The "blindness" is believed to be caused by the visual disruption. Psychologists (e.g. O'Regan, Rensink, Clark, 1999; Rensink, O'Regan & Clark, 1997) have pointed out that normally a change is associated with a transient change. A transient change means an abrupt change of signal, in this case a visual signal. It draws attention and we thus localize the change (O'Regan, 2001). However, a visual disruption covers the whole scene. When the scene re-appears, there is a global transient change.

Attention is not drawn to the specific region where the target change occurred; therefore, we cannot detect it.

One of the common paradigms in CB is the "flicker" experiment (Rensink, O'Regan & Clark, 1997; 2000). Two highly similar scenes are involved in each trial. For example, if the change is the disappearance of a pen, one of the photos shows a pen on the desk and the other version shows a desk without the pen. Two stimuli are presented one after another and a blank screen is shown in between them. Participants are asked to look for the change and respond at once when they find the change. The presentation time of each scene is usually short, e.g. 250ms. The alternations of scenes repeat until a response is given or the trial is timed-out. Since the whole scene is replaced by a new scene after the blank screen, the transient change of addition/deletion of the pen is accompanied by the other re-appeared objects (e.g. ruler, rubber). It becomes difficult for participants to detect the change (Simons, & Levin, 1997).

To explain the low detection rate, psychologists tried to understand the change detection process. Simons and Levin (1997) captured that in a review of CB, "change detection is an active searching process in which individual objects are encoded and compared sequentially across views" (Simons & Levin, 1997, p263). An active searching process means attention is allocated voluntarily to each possible target in the first scene, named as the pre-change scene. Then we compare the encoded pre-change scene with the second scene, i.e. the post-change scene. If we have detailed information and we are able to retrieve it, we could identify the change without difficulty. However, if we do not encode detailed information, or we are unable to retrieve it, we cannot do the comparison. Therefore, failure in change detection could be due to i) a lack of detailed information, even though we think we see many things, (implying that we do not keep the information; it is lost while we are no longer attending to the scenes), or, ii) a failure in the retrieval process, (assuming that we had kept the information but could not retrieve it.) Either reason could lead to change blindness. The once obtained visual information may be lost easily and may not be accessible.

An example could illustrate the subtasks and their underlying processes. When showing two highly similar cups to you, you would perceive a difference in the appearance. However, when being asked what was the difference between two cups, you need some time to spot the difference. You are attending at one of the cups while recalling the appearance of another and comparing them when you are searching. You may not figure out the difference, if you have never memorized details of the cup or if you had forgotten the details.

The possible causes of CB and other topics covered in CB, such as the critical conditions of change blindness induction (e.g. Turatto, Bettlla, Umiltà & Bridgeman, 2003; Rensink, O'Regan, & Clark, 2000) and the role of memory on change detection (e.g Pashler, 1988; Wright, Green, & Baker, 2000) have provided important insights on questions like the influence of attention on visual information processing and the stability of encoded visual information. According to Rensink (2001), the studies of change blindness have a large add-on value to current study on human visual processing. It could solve the "mid-level crisis". He reasoned that vision is believed to consist of three levels of processing. Studies like visual search dig out influence of image properties on processing, which is the first level (low level). On the other hand, studies concerning abstract knowledge e.g. semantic properties of the input represent the advanced level (high level). There is always a missing linkage between these two levels, i.e. the middle level which binds primary visual input and the stored concepts. He believed that the huge influence of attention on change detection, (e.g. Levin & Simons, 1997; O'Regan, Deubel, Clark, & Rensink, 2000; Rensink et. al. 2000) would be a strong evidence that attention is the necessary glue applied to combine low level information with high level ones.

Visual Processing and Change Blindness

Attention and Change Blindness

Consistent with Rensink, many psychologists (e.g. Walter, & Dassonville, 2005; Pearson, & Schaefer, 2005) agree that attentional allocation has an important influence on change detection. O'Regan (2001) has highlighted that in normal situation, visual transients help us localize the change and we know where the change took place. The locational information is denoted as the "where" information. It draws observer's attention exogenously to the location of the change but does not indicate what the change is, e.g. a color change or a deletion change. In addition, some studies also indicate that attention helps us to locate the change. Landman, Spekreijse and Lamme (2003) studied the effect of cuing. They used a display, with eight rectangles oriented at 0^0 or 90^0. Participants had to detect a change in the orientation of one of the rectangles. The time of cue presentation also varied from before the first scene to after the second scene. Detection rate was much higher in the cued condition than in the uncued condition, and a cue presented after the second scene did not improve detection performance. Besides explicit cue which can be used to affect allocation of attention, Scholl (2000) showed that late onset stimuli, which captured attention, can speed up change detection. In his experiment, an additional step to the traditional flicker experiment was inserted. Before scenes start to alternate, the first scene contained several objects on it was shown first. After 200ms, one more object was added, i.e. the critical object. The newly added object captured attention exogenously. A short time later, the alternation began. Results showed that change detection was easier for the critical object. In brief, when participants were asked to locate the change, they responded faster in situation where their attention was near/ on the change region.

Furthermore, later findings showed that attention is also closely associated with the "what" information, i.e. description of the object (O'Regan, 2001). The "what" information corresponds to the memory, which observers have, for the pre-change objects. In the change detection process, when observers are searching for the change, they are comparing the post-change scene with the memory of the pre-change scene. The abstract knowledge (e.g. name) of the pre-change objects allows observers to identify what is being changed. Studies on region of interest (e.g. O'Regan, Rensink, & Clark, 1999; Shore, & Klein, 2000) show a higher detection rate in the central interest region than in the marginal interest region. They found that the central interest region was compared before the marginal interest region. So change in central interest region would be found more quickly. The "what" information of objects thus affects the attending sequence.

Corresponding to the above findings, theories of visual processing that highlighted the role of attention in explaining CB were developed. According to various attention-based theories of CB (Scholl, 2000), participants show better performance in detection task if they are attending to the object which is going to change i.e. target. One of the advocates, Rensink, had developed an attention-based account of CB, i.e. coherence theory (Rensink, 2000a; Rensink, 2000b; Rensink, 2001). He stated that across scenes, little information is kept; except those under focused attention. In the model, the visual system consists of three separate systems (Figure1). The low-level system (System I) copes with highly detailed information. It forms many proto-objects but the information is highly volatile. It gives us the sense that we "see" everything. For example, we see pens, files and desk in an office scene. The second system (System II) is an attentional one. It processes information under focused attention. It obtains information from System I and gives a stable representation of the physical properties of the object. From this system, we know a particular pen is blue in color and has an approximate length etc. Finally, System III processes spatial layout and gist (abstract meaning of the scene), i.e. the overall meaning of the scene and the spatial arrangement of objects. In contrast with System II, System III is a non-attentional system. Most of its work can be done in the absence of focused attention. Its information is fed to System II. This enables us to form a complete and stable representation of the focused object with its physical properties as well as spatial and non-visual information, which can be derived from visual information (e.g. semantic identity). A change that occurs to that object can be detected, but a change that occurs to another unfocused object cannot. Thus, the theory draws strong links between attention and change detection. Only under focused attention can a change be seen. In addition, this theory states that once focused attention is shifted, the stable form dissociates back to a proto-object. Therefore, a change that occurs to a proto-object will be undetected. Our memory on its physical properties was not readily accessed due to its instability.

The coherence theory as well as other attention-based theory of CB (Beck, & Levin, 2003; Rensink, O'Regan, & Clark, 1997) support the first cause of CB from Simons and Levin (1997) as being lack of information that support real time change detection. The attention-based theory, however, leaves little room for the second possible cause of CB, i.e. failure in the retrieval of pre-change scene information (Simons & Levin, 1997), since

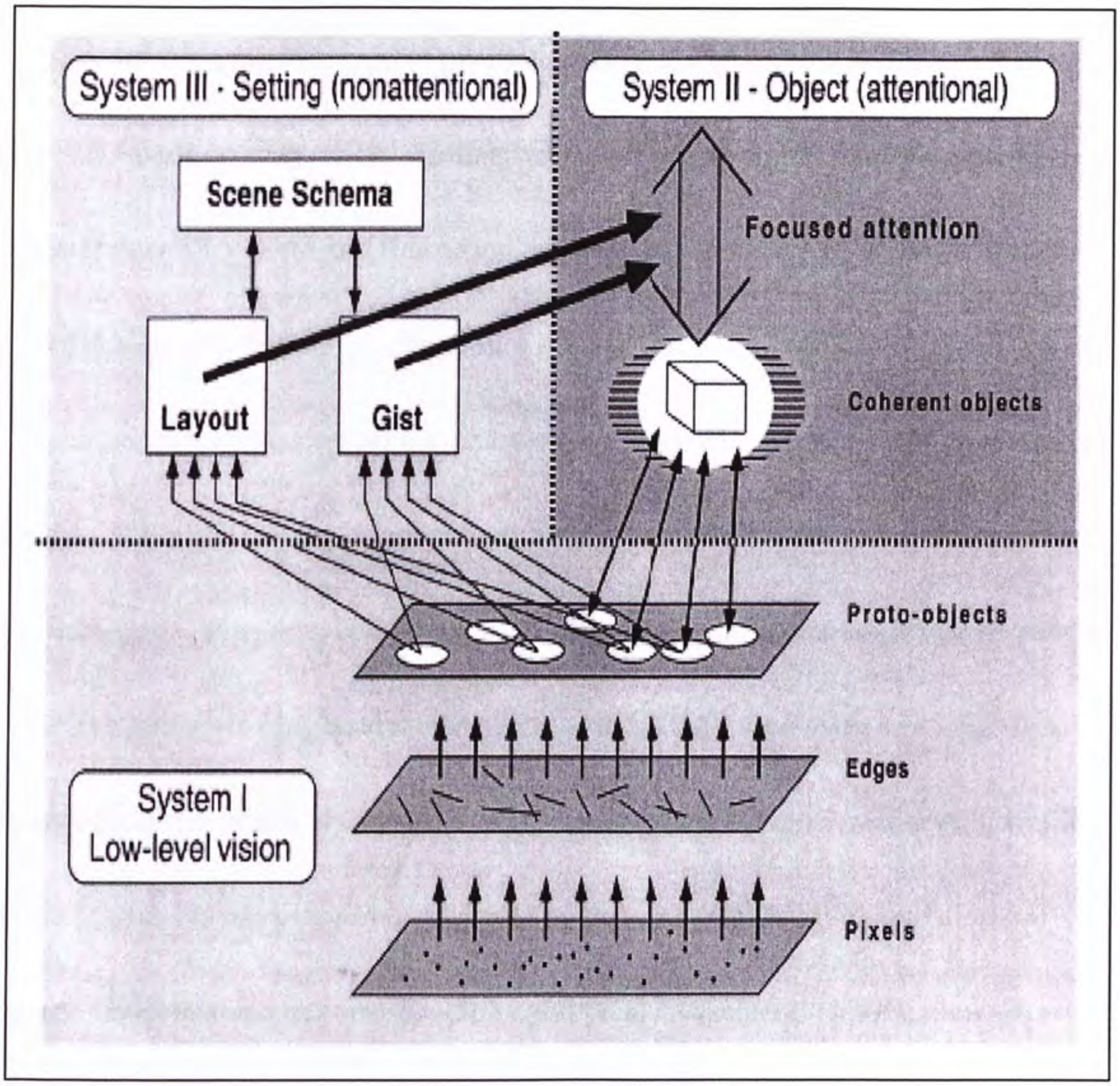

Figure 1. Triadic architecture of the coherence theory. Visual processing is done via the interaction of three separate systems. System I: low-level system copes with visual detailed to form proto-objects. System II: Runs under focused attention to form a stable representation of the object. System III: A non-attentional system, process spatial information and scene gist (Rensink, 2000b).

according to the coherence theory, we do not retrieve information for real time change detection

Different from the above, other psychologists proposed another account of CB. One of them is the visual memory theory (Hollingworth, & Henderson, 2002; Hollingwoth, 2003). According to Hollingworth and Henderson, we have a detailed visual description of the attended object. This description includes abstracted form of low-level visual properties (e.g. brightness, color) and conceptual information such as the object name. This information is combined with spatial layout information to form an object file (Kahneman & Treisman, 1984; Kahneman, Treisman, & Gibbs, 1992). Afterwards, the object file would be stored in short-term memory. In long term memory, it also holds the information as a long term memory object file, which is more resistant to decay. The short term memory object file is similar to the stable representation suggested by Rensink (2000b). With attention, we recognize the object and its corresponding conceptual and semantic information are activated. However, when attention shifts, the information is lost. In contrast, a long term memory object file accumulates information of previously attended objects. Participants can detect changes to those objects when they re-fixate the object. Through re-fixation attention returns and the corresponding information is retrieved. Therefore, the cause of CB is failure in retrieving the long term memory object file. Hollingworth (2003) conducted an experiment showing that a cue presented after the initial encoding process of the pre-change scene boosts change detection. In the experiment, the pre-change scene was presented for 20s together with an abrupt onset / offset of an object. Afterwards, the pre-change scene was shown for 200ms followed by a mask. Then, the post-change scene was shown. Sometimes during the post-change scene, a cue was presented, indicating a specific object; the object may be the target or may not be. Participants had to decide if it was the object being changed. Result showed a nearly 90% accuracy in those trials, compared with trials, which was about 75% accurate in times, without the cue. He claimed that the cue assured a re-fixation of the object and helped participants in the retrieval process. Apart from that, Zelinsky (2001) had studied on factors related to stability of memory, he showed that the number of objects showed in the pre-change scene (i.e. set size) exerted influence on the change detection rate. He used a flicker paradigm and pre-change scenes consisted of object array in different set size. There were three different set sizes 1, 3 and 9. Result showed that the error rate and response time increased as set size increased. Therefore, the memory constraint was a possible cause of CB. Together with other studies of the influence of memory in CB (e.g. Hollingworth & Henderson, 2000), it could be concluded that with a suitable guidance of attention during the comparison process of the scenes, the missing rate in change detection would be reduced.

In brief, studies of CB have inspired two groups of psychologists proposing different visual processing theories. The coherence theory (e.g. Rensink, 2000b) stated that attention is necessary for change detection. Only change that happens to an object that we are attending can be detected. Attention has a glue-like effect, binding low-level visual information, with spatial layout and gist forming a stable representation of the attended object. Another camp proposed the visual memory theory (e.g. Hollingworth, & Henderson, 2002). In addition to the glue-like effect of attention, the comprehensive information of previously attended objects is stored in long-term memory, forming a long term object file. Information within the memory is not lost even when attention is allocated to other objects in the scene. Re-visit of previously attended region could help change detection. The focus in CB on visual processing is not on the properties of visual memory, e.g. its capacity, but it is on the way we use the information. From Rensink, we do not use the encoded information for scene comparison, but for Hollingworth, we do so.

Different Types of Memory and Change Blindness

Despite the disagreement about the importance of memory retrieval in CB, the coherence theory (Rensink. 2000b) and the visual memory theory (Hollingworth, & Henderson, 2002) both incorporate three kinds of visual information in processing. They are: low-level image properties (e.g. brightness and color); spatial layout of scene and gist; and conceptual information of the object. Studies have been conducted to understand attentional demands in the processing of these three kinds of visual information. They generally found that the attentional demands differ, the encoding of spatial layout can be done automatically (e.g Aginsky, & Tarr, 2000; Germeys, et. al. 2004; Hollingworth, 2005), and the processing of gist information can be done under divided attention or in the near absence of attention (e.g. Li, VanRullen, Koch, & Perons, 2005; Moore, & Egeth, 1997). However, the encoding of low-level information seems largely depends on attention, (e.g. Aginsky, & Tarr, 2000; Rensink, O'Regan, & Clark, 1997).

Consistent with the above findings, the two main camps of theory in CB also make similar theoretical accounts in the processing of different visual information. Within the coherence theory (Rensink, 2000b), spatial layout and gist information can be encoded in the absence of attention. It separates the abstract information from an object's visual details. There is also such a separation between spatial layouts and visual details in the visual memory theory (Henderson and Hollingworth, 2003). Henderson and Hollingworth suggested that spatial layout information was specifically encoded while semantic information and an abstract description of an object's visual details are encoded when attention is allocated to the object.

Although the theories made distinctions about processing of different visual information, support for these distinctions from CB studies is incomplete. Usually tests on this issue are conducted through a comparison of detection rate in different kinds of change. A change in spatial layout is usually expressed in terms of the presence / absence of an object (i.e. deletion, addition) or change in the configuration among objects (e.g. Hollingworth, 2005; Pearson, & Schaefer, 2005). Change in conceptual information is induced by a replacement of an object with one from a different conceptual category to the original one (i.e. type change) (e.g. Henderson, & Hollingworth, 2003; Hollingworth & Henderson, 2002). Lastly, change in visual details could be in terms of object replacement, in which the new object belongs to the same conceptual category as the original one (i.e. token change). It could also be a change in a physical property of the original object (e.g. color change, or rotational change) (e.g. Henderson, & Hollingworth, 2003; Hollingworth, 2003).

Across studies, there are two main findings. First, detection rate of addition / deletion change is higher than type change, token change, color change and rotational change (e.g. Henderson, & Hollingworth, 1999; Henderson, & Hollingworth, 2003). It also takes less time to finish the task in addition / deletion change (Rensink, O'Regan, & Clark, 1997; Hollingworth, Schrock, & Henderson, 2001). This finding suggests that change in a spatial layout is easier to detect than change in other visual information, and could support the notion that spatial layout is of particular importance in scene processing and is specially encoded (Henderson, & Hollingworth, 2003). Second, changes to objects carrying central information of the scene could be detected within a shorter time than marginal interest objects (Hollingworth, & Henderson, 2000; Rensink, O'Regan, & Clark, 1997). This suggests the semantic meaning of an object in relation to gist affects the order of processing. It would imply that in the very early time of processing, semantic meanings of an object are processed so as to guide attention (Walter, Dassonville, 2005).

Nevertheless, comparison on detection rate between type change and token change are lacking. Although, Henderson and Hollingworth (2003) have tried to examine differences in detection rate between type and token changes, they did not find a significant effect. Hit rates in both conditions were similar, and both were significantly lower than deletion which was around 80%. This result is inconsistent with the visual memory theory (Henderson, & Hollingworth, 2002). In the type condition, both semantic and visual details may help detection, while the only difference in the token condition in visual details. Therefore, information used in detecting token changes and type changes would be different. If we assume detection rate increases with the amount of information available for comparison, superior performance in detecting type changes would be predicted.

Summing up the theories, both Rensink and Hollingworth agree that spatial layout is handled in the very beginning. Especially in Rensink's theory (2000b), spatial layout and gist can be encoded with low attentional demand. The opposite occurs in the encoding of visual details, which is done under focused attention and would become volatile once attention shifts. In contrast, in Hollingworth and Henderson's theory (2002), conceptual information and abstract representation of visual information are durable once they are encoded under focused attention.

General overview of the paper

Outlining ideas in change blindness studies, there are two camps holding different ideas towards the relationship between attention and encoded visual information. They agree on the idea that attention is needed to encode information. However, they disagree on the involvement of encoded information in change detection. Henderson and Hollingworth (1999) claims that focused attention on the target is not needed to detect the change because participants can recall the previously attended information when they re-fixate the target. So there are three possible outcomes in Hollingworth's task, a) a change is detected immediately; b) a change is detected when participant re-fixate the target; c) a change goes undetected. In contrast, Rensink (2000b) thinks that attention had to be allocated on target when change happens and there are two possible outcomes, the change is either being detected immediately or it would not be detected. Each of them provided supportive, however, it is difficult to generalize the importance of re-fixation in Rensink's experiments due to differences in experimental setting. So the importance of attentional allocation on post-change scene in CB is unclear.

To cast light on this issue a comparison between their experimental setup can be done. First of all, stimuli used in CB are novel to observers; the length of presentation time should be controlled. From Rensink's experiments (Rensink, 2000b), the presentation time of scenes are short. An example would be the experiment by Beck and Levin (2003). The scene was displayed once for 2000ms. In the flicker paradigm where scenes are shown more than once, presentation time is between 150ms to 250ms in each display (e.g. Rensink, O'Regan, Clark, 1997). Opposite to them, the presentation time is much longer in Hollingworth's experiment. It can be as long as 20s for encoding (e.g. Hollingworth & Henderson, 2002; Hollingworth, 2005). From the time spent, memory formed could be very different and the ability in retrieving the encoded information for scene comparison differs. Castelhano and Henderson (2005) have addressed this issue, agreeing that the long encoding duration would allow participants to use a memorization strategy rather than normal scene viewing. They thus cut the presentation time to 10s. However, this un-interrupted viewing time is still much longer than 250ms.

In addition, the effort paid in monitoring attentional allocation in two camps varies a lot. In the flicker paradigm, it has been commented by Hollingworth and Henderson (2002; Hollingworth, 2003) that there is no way to monitor the allocation of attention before and after the change happens. The undetected change may not be attended before the change happens. Following this comment, Hollingworth and his co-workers performed change blindness studies in the saccadic paradigm, in which eye-movements are closely monitored.

Hollingworth's experiments favor the use of memorization strategy which favor the claim that re-fixation helps change detection whereas Rensink's experiments do not often include the idea of re-fixation. Thus, attentional allocation of post-change scene on change detection is not well understood and it would be covered in this paper. There are several differences in the current setup with the traditional flicker experiments and saccadic experiments in order to bring both theories into consideration. First, a one-shot experiment, which provides participants a close to normal viewing condition, was adapted (Pearson, & Schaefer, 2005). Second, the presentation duration is adjusted to 3s. This presentation duration is used in a "mudsplashes" experiment, which claimed to support the argument that representation of the world is spares (O'Regan, Rensink, & Clark, 1999). In both the "mudsplashes" experiment and the one-shot experiment, the pre-change and post-change scenes are only shown once each. If finding supporting the attention-based theory is still found, the presentation time (3s) might not allow observers to memorize details of the scene. The presentation time may not bias to the visual memory theory. Third, instead of using an eye-tracker to monitor attentional allocation, cues were used to manipulate attentional allocation to different regions of the scene. This could still ensure that information about the target is very likely to be attended before the change happens. Therefore, the doubt in the traditional flicker paradigm on whether the properties of pre-change object are encoded could be eliminated.

Furthermore, another related issue on the discussion of encoded information is the difference in processing between three kinds of visual information: spatial layout, conceptual information and visual details. To investigate this issue, a method similar to previous CB studies was used. Detection rate of three kinds of changes: deletion, type and token were compared. Through comparison of the ease of detection of the different change, we can determine the availability of different information. On the other hand, O'Regan (2001) has raised the concern in generalizing result from CB studies to the stability of encoded information. He suggested that the blockage of visual transient change led to observers' inability in locating the location of the change. This is the localization or the "where" task only. To perform the "where" task without visual transient change, observers compare spatial information between the pre-change and post-change scenes. Other information like color of the object, name of the object is not necessary. Therefore, it is inappropriate to draw implication on non-spatial memory of the encoded objects. Those are information relate to "what" task, i.e. observers have to know / point out what the change is. In other words, in CB studies precaution has to be taken to ensure "what" information are probe by the task. Thus, questions related to semantic category and visual details of the object were asked in addition to localization task. The current experiment is rarely done in an experimental set-up but has been used in CB studies conducted in a real-world setting (Simons, Chabris, & Schnur, 2002). It is hoped that addition insight regarding to the processing of different visual information can be found.

Experiment 1

The study by Simons, Chabris, & Schnur, (2002) included "what" tasks in the experiment conducted in the real world. Although this kind of study has higher external validity than those conducted in the laboratory, there is a trade-off in the control over attentional allocation. Eye-movements and attention during the pre-change scene would be difficult to monitor. Its compatibility with experiments by Rensink and Hollingworth would also be weak. It is difficult to make comparison among experiments. Therefore, “what” tasks should be included in CB experiments in laboratory settings. Some previous studies (e.g. Angelone, Levin, & Simons, 2003; Beck & Levin, 2003; Mitroff, Simons & Levin, 2004) replaced the typical judgment task i.e. respond once the change occurs, with a recognition tasks. For example, in the recognition task by Beck and Levin (2003), several objects were shown; participants chose the one which was changed across scenes. This could be a kind of “what” task, as non-spatial information was required. However, stimuli included were objects arrays showed in an imaginary grid instead of naturalistic scenes in traditional studies. The study by Angelone, Levin and Simons (2003) investigated the association between change detection performance and performance in recognition task. They test the availability of “what” information when participants fail the change detection task. They found that despite the low change detection rate, ranging from 6% to over 50%, the recognition rate was well above chance level. In the recognition task showing four options, the accuracy was between 63% and 81%. These shown that we have pre-change object representation. Besides recognition task, another kind of “what” tasks would be asking questions concern about the name and the color of the target object, which is used in Simons, Chabris & Schnur (2002). It tests directly on the stability of conceptual information and visual details of the target object.

In Experiment 1, the latter one was incorporated into a one-shot paradigm.

The one shot paradigm is highly similar to a flicker paradigm, but the pre-change scene and the post-change scene is only shown once. One-shot paradigm is better than the flicker paradigm in terms of external validity, since scenes are only altered once and there is an absence of non-stop interruption while viewing. Thus, it close to normal viewing. In the one shot paradigm, a modification was made. Many studies using the one-shot paradigm (e.g. Ando, 2000; Becker, Pashler, & Anstis, 2000; Miranda, *et. al.* 1992), similar to the flicker paradigm, had a presentation time of scenes less than 1s. Participants do not have enough time for complete viewing (Pearson, & Schaefer, 2005). Therefore, a longer presentation time (3s) for the pre-change scene was adopted.

Experiment 1A

Experiment 1A was conducted as a test of the stimuli and the overall paradigm. It was a one-shot paradigm, in which both pre-change and post-change scene were presented once. A blank screen was presented in between two scenes. It also provided information on the baseline performance in different tasks and changes under uncued conditions.

Also, Experiment 1A compared detection rates (localization performance) in different kinds of changes. The coherence theory (Rensink, 2000b) and the visual memory theory (Hollingworth & Henderson, 2002) would have a similar prediction on the differences in detection rates between deletion, type and token changes because of different kinds of information involved. However, this result was not found in previous study (Henderson & Hollingworth, 2003). In Experiment 1A, first, similar to other CB studies, different information, i.e. spatial information, conceptual information and visual details, was represented by a particular kind of changes: deletion, type and token, respectively. *Deletion* meant that an object disappeared in the post-change scene (change in spatial information). *Type* meant that an object was replaced and the replacement was from a different semantic category and had different visual details (change in semantic information and visual details), e.g. a cup was replaced by a bottle. *Token* meant that an object was replaced by another member of its semantic category (change in visual details only), e.g. a cup in yellow with one handle was replaced by another orange cup with two handles. As suggested, both theories proposed that spatial information was highly important and observers were more sensitive to change in spatial information than other kinds of information. Deletion would be the easiest to be detected.

The second method of investigating difference in processing of the three kinds of information was the "task". In this experiment, the "where" and "what" tasks were separated. The "where" task, was localization. Participants had to indicate the region of change (target region). The "what" tasks assessed participants' memory on two kinds of information: conceptual information[1] (through an object naming task) and visual details (a color labeling

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[1] There maybe disagreement on whether object naming is a semantic or a conceptual task, since one may argue that the name is simply a label that devoid of semantic meaning. However, it was not the main concern of the paper. My intention of using an object naming task is to separate the abstract idea from the description of

task). Within this manipulation, performance in "what" tasks and "where" task cannot be directly compared. Participants received feedback in localization to ensure they are likely to draw information (if any) from the correct object during the "what" tasks, but this feedback was obviously an additional cue for the "what" tasks. Therefore, if performance in "what" tasks was found to be higher than in localization, it could be related to the additional cue. We therefore could not conclude a difference between processing in spatial information versus the "what" information. Performance in object naming and color labeling can reflect stability of the conceptual information and visual details as well as the task difficulty. It was predicted that performance in object naming and color labeling would be better than chance. Under Rensink's coherence theory (2000b), the semantic information would be obtained when participants obtaining the gist information while the visual details would be encoded under focused attention.

Methods

Participants

15 CUHK students participated in the experiment. They received $20 compensation at the end of the experiment.

Materials & Apparatus

Stimuli were 68 real scene photos. The image sizes were 640 * 480 pixels, 22.58 * 16.93

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object's visual properties only. Since name is an abstract idea that deviated from description of the image properties obtained from visual inputs, it is adopted as a conceptual task.

cm. Each kind of change, was created using Photoshop (Adobe System Inc.) from the original one. Altogether there were four versions for a particular scene: pre-change, deletion, token and type (Figure 2). The size of replacement was controlled.

An eMac computer with the RSVP software (Williams, & Tarr, 1998) was used to run the experiment. Scenes were presented on an Apple 17" color monitor, showing a resolution of 640 * 480, 120Hz

Design and procedure

In this experiment, the first independent variable is the different kinds of change (deletion, type and token). In the deletion condition, the changed object would be removed. In the token change, the object was replaced by another object belonging to the same category but with different visual details e.g. color. In the type change, the changed object was replaced by another one which belongs to a different semantic category. Each trial started with a fixation point in the centre of the display. The pre-change scene was presented for 3000ms continuously. Then a blank screen was displayed for 500ms followed by a post-change scene which was shown for 500ms. Participants responded using the number pad with only four keys labeled as 1, 2, 3 and 4, representing the 4 quadrants of the scene. Other unused keys of the number pad were covered and deactivated. There were a total of 68 trials with the first four serving as practice trials. Test trials would only proceed when the participants understood their tasks. There was a short break after the 32^{nd} test trial. After

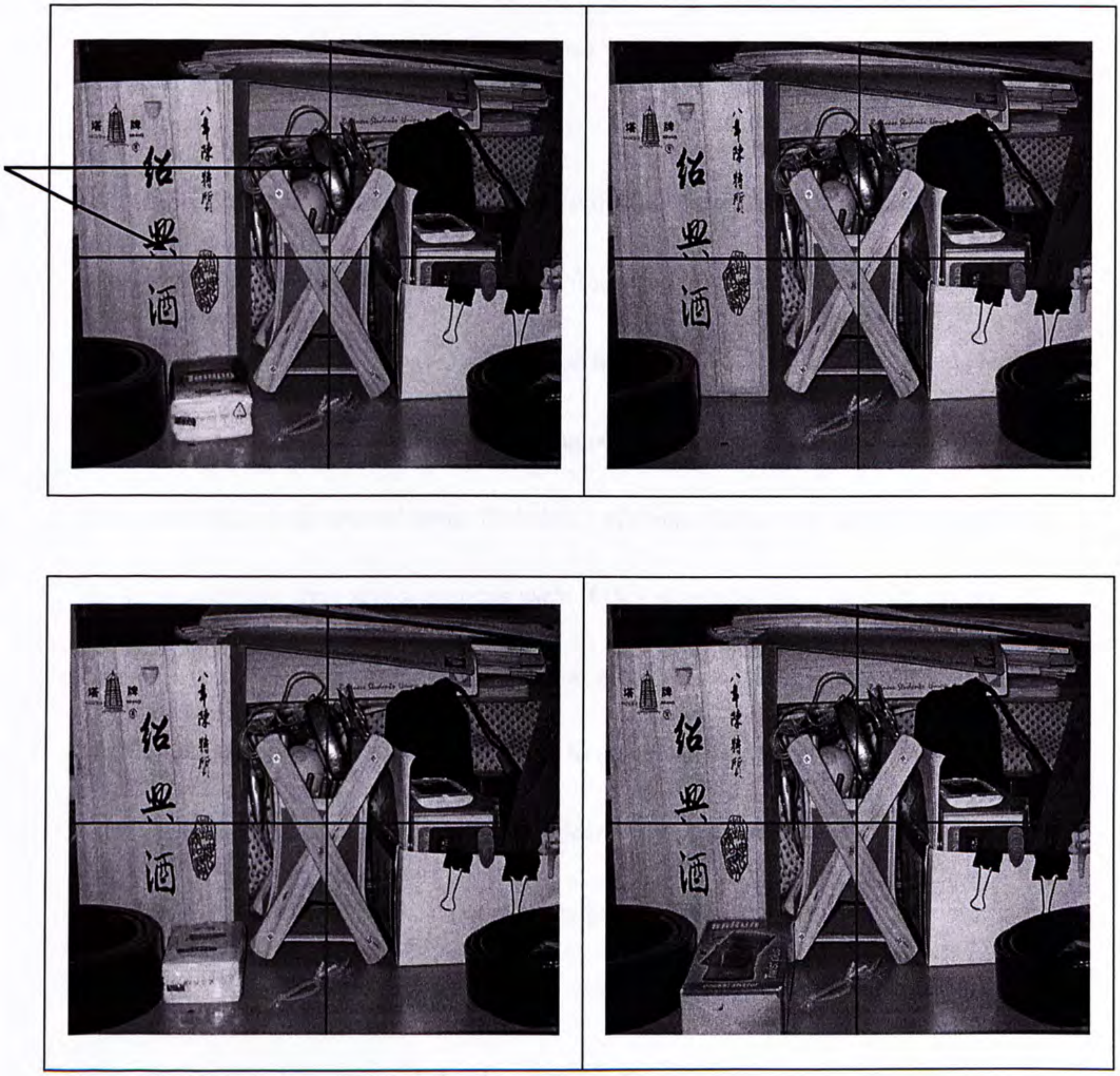

Figure 2. Examples of stimuli: a pre-change scene (top left); a deletion scene (top right); a token change scene (bottom left) and a type change scene (bottom right). Two arrows are pointing at lines forming a red cross which divided the scene into four quadrants. (In the experiments, color version of scenes was used.)

summing up across participants, each set of stimuli was presented equal number of times for each kind of change. Participants only saw each set of photo once. The experiment lasted for 20 minutes.

The second factor was the different kinds of task. In each trial, there was always a change. First, they had to localize the change (localization). Participants indicated the quadrant that contained a change (i.e. the target quadrant). To do this, all presented photos were divided into four quadrants (upper left, upper right, lower left and lower right) by a red cross running from the central point. Probability of change occurrence in each quadrant was the same and there were seventeen trials each. If they were unable to locate the change correctly, feedback indicates correct region was given before asking questions.

After localization, two questions related to the pre-change target object were asked. In each question, there were four options. Participants used the same keys to respond. In the first question, they had to choose the color of the target. The second question was an object naming task. The distractors in each question were answers in other trials. Distractors may / may not appear in that particular scene. There was no time limit, but participants were instructed to respond as fast as they could while maintaining their accuracy. The size of change was controlled, so that the average size of changes occuring in each quadrant was similar.

To analyze the result, repeated measure ANOVA would be used. Tasks are treated as one of the within subject factor and it could be expected that there are differences between performances of different task (main effect of task), due to the different nature of tasks. However, through interacting with another within subject factor, change, properties of encoded information could be reflected. If deletion, type and token change are the same, difference found in task A would be similar to the difference found in task B. When there is an interaction, the underlying processing maybe different for different changes. Therefore, the point of interest is on the relative differences among changes in different tasks. Furthermore, the main focus in this thesis is the role of attention in change detection. To simplify the comparison, tasks' performance are analyzed in one ANOVA.

Result

Results are shown in Figure 3. A repeated measure ANOVA of a 3 (task: localization, object naming and color labeling) * 3(change: deletion, token and type change) design was conducted. The main effect of task was significant, $F(2, 28) = 94.92$, $p < .05$. Object naming was the best performed, with performance in localization intermediate between object naming and color labeling. In the pair wise comparison, performance in the localization task was significantly worse than the object naming task $t(14) = 3.1$ $p < .01$ and it was better than the color labeling task, $t(14) = 11.01$, $p < .01$.The pair-wise t-test between color labeling and object naming was also significant, $t(14) = 10.93$, $p < .01$. The main effect of change was also significant, $F(2, 28) = 3.33$, $p < .05$. Participants performed better in deletion trials than in token change trials, $t(14) = 2.92$, $p < 0.2$, but other comparison were non-significant; for

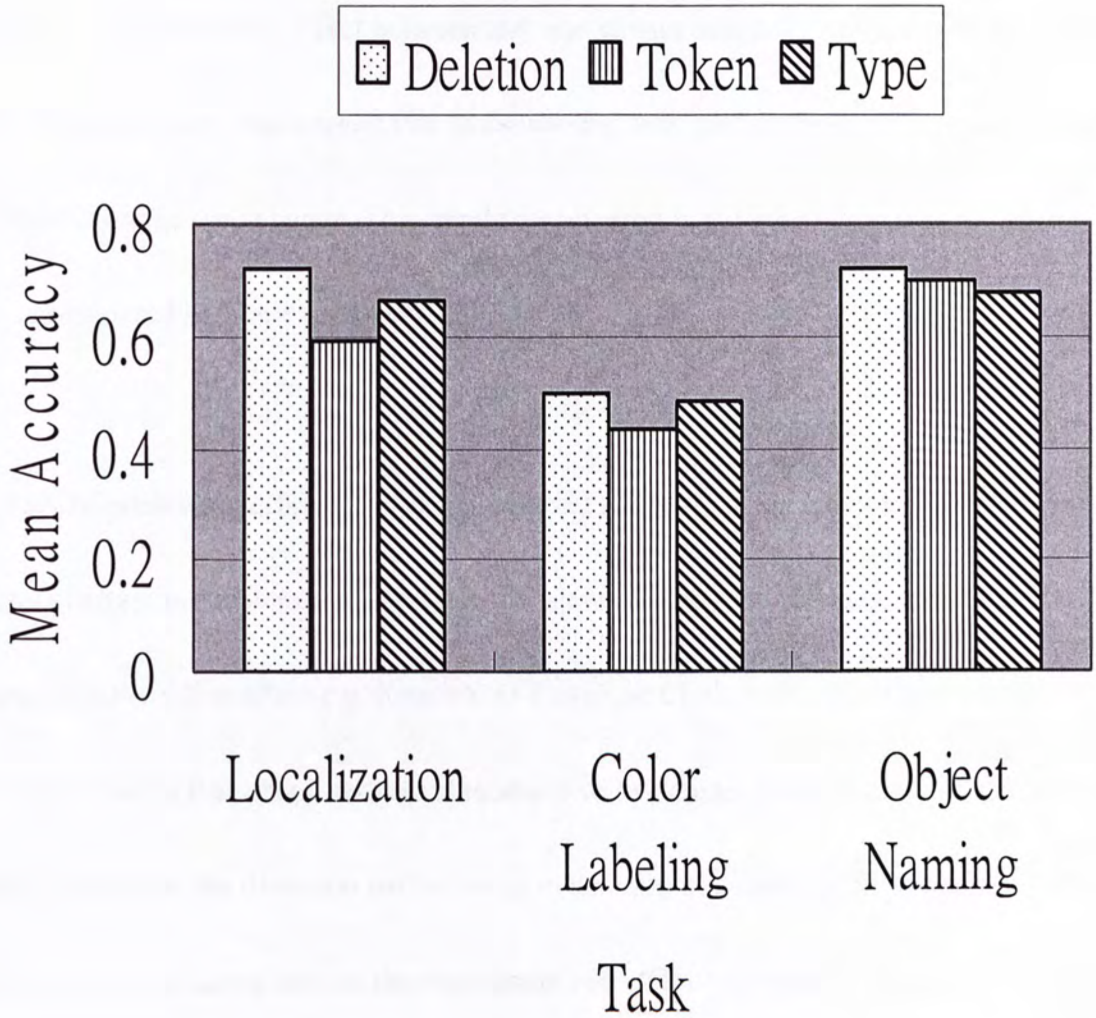

Figure 3. Mean accuracy for different tasks under deletion, token and type change conditions in Experiment 1A.

deletion and type comparison, $t(14) = 1.06$, $p>.05$; token and type, $t(14) = 1.53$, $p>.05$. In addition, the interaction effect between task and change was not significant, $F(4,56)=1.17$, $p>.05$. However, there was a trend that in the naming task, performance of the token change was better than the type change. This trend was reversed in the other two tasks, and will be further considered in later experiment.

Discussion

The difference in performance along different kinds of changes showed that detection of deletion changes are easier than detection of both token and type changes. It replicated findings in other CB studies (e.g. Rensink, O'Regan, & Clark, 1997; Hollingworth & Henderson, 2002), that observers are more sensitive to changes in spatial layout than other changes. However, the detection performance in deletion trials was far from perfect. It shows that the stimuli and setup used in the experiment can effectively lead to change blindness.

Regarding the superior performance in object naming than localization, this could reflect a sequence effect as mentioned earlier. Object naming was done when participants knew the target quadrant. Performance in object naming may be boosted by the additional spatial information. Although, it would still reflect participants' ability in retrieving the scene, it is inappropriate to imply that conceptual information is better encoded than spatial information. Furthermore, feedback was given if participant failed in choosing the target region during localization task. The feedback may help participant recall information about the target region

(Simons, Chabris, & Schnur, 2002) and when answering the color labeling and object naming task, their performance went up.

In spite of the confounding encounter in comparing stability of spatial and conceptual information, comparison on difference in performance between color labeling and object naming could reflect differences in the stability of the memory between visual details and conceptual information. With the assumption that encoded information has higher stability than unencoded information, the better performance in object naming than color labeling reflects a higher stability of conceptual information than visual details. It might mean that conceptual information is encoded more frequently than visual details. This meets with Rensink's coherence theory (2000b) that visual details are less stable than conceptual information.

Experiment 1B

In Experiment 1A, the stimuli and experimental setup was tested to ensure that these can cause change blindness. In Experiment 1B, the influence of attentional allocation in pre-change scene on information processing in CB, i.e. the stability of pre-change scene memory under different attention conditions in pre-change scene was investigated. Difference in allocation of attention a short time before the change was manipulated by cue. There were three cuing conditions: valid cue, invalid cue and uncued. With a valid cue, focused attention would be directed to the target region just before the change occurred, so that information from the target region should be encoded just before the change. With an invalid cue, attention directed away form the target region just before the change. These cued situation contrast with uncued condition, where attention was not specifically guided in the whole trial. Since subjects did not know where to attend, they would likely try to encode as much information as they could to perform the detection task; however, the information encoded may be less specific (Treisman & Hayes, 1992). Across three cuing conditions, the detection rate was expected to be highest in the valid cue condition and lowest in the invalid cue condition. Also, the valid cue condition ensures that information of the target region is encoded.

In addition, importance of allocation of attention in post-change scene may exert great influence on stability of encoded information. In coherence theory (Rensink, 2000b), attention helps maintain visual details. In visual memory theory, Henderson and Hollingworth (2003) showed that participants often detect a change when they re-fixate the target region. This suggested that re-fixation of the target region i.e. attention allocated to target region, could help participants retrieve encoded visual information by the additional spatial information. In order to separate the effect of attentional allocation of pre-change and post-change scene, allocation of attention in post-change scene was controlled. In Hollingworth (2003), allocation of attention in the post-change scene was controlled by an additional cue, indicating a particular object. Participant's task was to decide if the object was changed. However, the control condition was a typical change detection task, in which participants had to find out the change in the absence of guidance. The task difference reflects that the control condition differed from the test condition with more than one factor. Therefore, instead of using an external cue, a visual disruption is intentionally not included in the experiment, so that motion transient accompanied with change can guide attention to target region (Rensink, O'Regan & Clark, 1997). This although lead to high accuracy in localization and typical CB phenomenon would not be seen; stability of encoded information can still be studied in the "what" tasks. It also shows the importance of the separation between "where" and "what" task. Also, with data from Experiment 1A that visual disruption was used, influence of attentional allocation in post-change scene could be studied in later section as well.

Methods

Participants

32 CUHK students participated in the experiment, which took about 20 minutes to complete. Some joined the experiment to fulfill course requirement, others received $20 compensation.

Materials & Apparatus

The same 68 real scene photos were used. In addition to the four versions from Experiment 1A, for each scene, another 6 versions were made. Four of them were cued scene and the other two were uncued (Figure 4). Other apparatus used were also same as Experiment 1A.

Design and procedure

In addition to the two independent variables in Experiment 1A, a third independent variable was added: cue. There were altogether 3 cuing conditions which included valid cue, invalid cue and uncued. In trials where a cue was present, it correctly indicated the region where a change would occur, 75% of the time (valid cue). The cue therefore was invalid for the remaining 25% of the time. Two of the red line segments cutting the scene into four quadrants would be changed to yellow. They formed a boundary, enclosing a quadrant in the cued condition, while in the uncued condition, the yellow lines formed a straight line. Thus, no region would be bounded in the uncued region. The second difference between this experiment and Experiment 1A was the omission of a blank screen. In this experiment, cued scenes were same as the pre-change photos except the color of line segments. Therefore, participant can encode pre-change scene information form cued version as well. To keep the total amount of presentation time for pre-change scene as 3000ms, the pre-change scene was presented for 2300ms initially. Then a cued scene appeared for 500ms. Afterwards, the pre-change scene displayed for 200ms. This is to eliminate the effect of a transient change from by the color change of the cross. Lastly, the post-change scene was shown immediately for 500ms and then disappeared. The disappearance of the scene signaled that participants

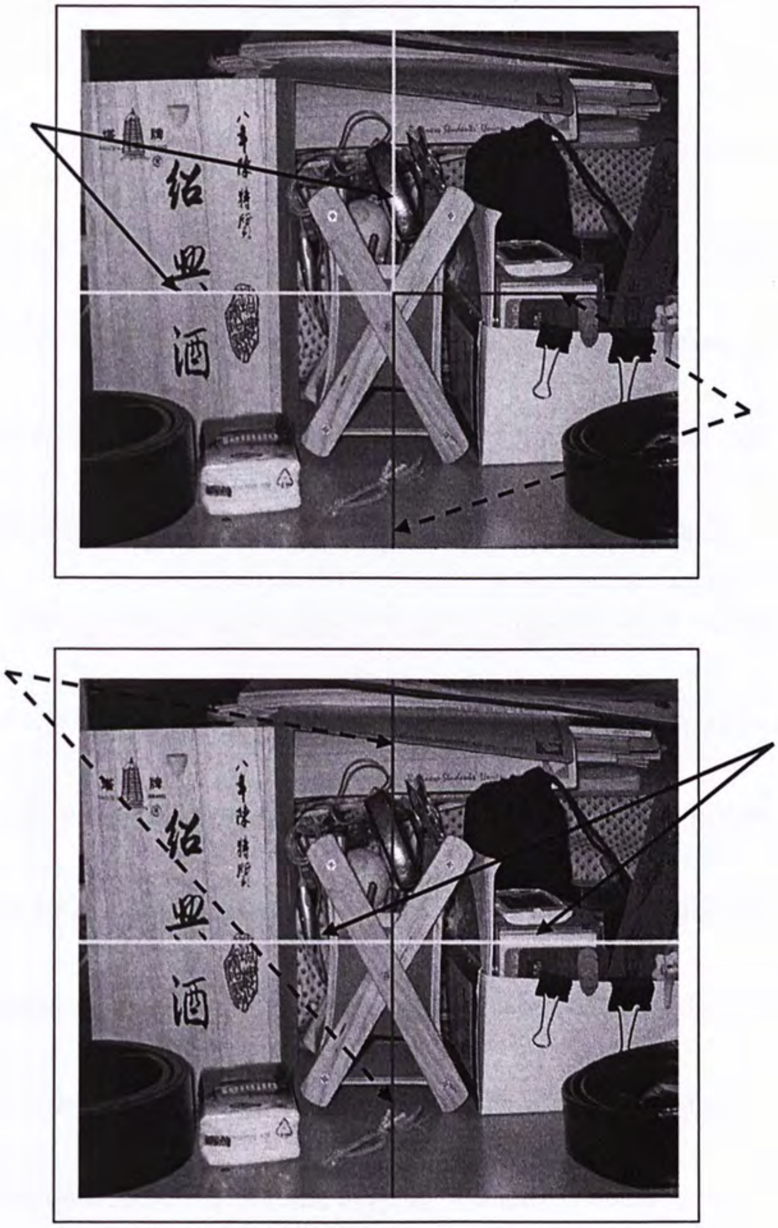

Figure 4. Examples of stimuli in Experiment 1B: The upper one shows a cued scene (invalid cue). Two black arrows indicate line segments in yellow, embedded quadrant 1 as the cued region, while the dashed arrows point at line segments in red. The bottom one is an uncued scene. The line in yellow formed a horizontal straight line. Line in red formed a vertical line. So that none of the quadrant is cued. (The color version of scenes was used when running the experiment.)

had to respond as they did in experiment 1A.

Result

This experiment was analyzed with the same principles as Experiment 1A. Repeated measure ANOVA was run. It was a 3(cuing) * 3 (task) * 3 (change) within subject design with accuracy as the only dependent variable. Among all interactions, only task * change is significant, F (4,124) =9.82, p<.05, others are non-significant: cue * task interaction, F (4, 124) = 1.20, p>.05; cue * change, F (4, 124) = 0.03, p>.05; cue *task *change, F (8, 248) = 0.03, p>.05. The significant interaction of task * change modified the main effect of change, F (2, 62) =8.42, p<.05. Figure 5 showed that subjects' performance in object naming under type change was worse than deletion and token change. This was different from the localization and color labeling tasks, in which type change were either close to deletion change or close to token change. Pair wise t-tests on the effect of change in object naming found that performance in the type change condition was significantly lower than both the deletion and token change conditions, F(1,31) ==20.50, p<.01 and F(1,31) =27.70, p<.01 respectively. This trend is only found in object naming task. In both localization and color labeling, performance trend goes from deletion, type change and token change.

Result also showed that the main effects were all significant, in addition to main effect of change. Among cuing conditions, F(2,62)=18.12, p<.05, performance with valid cues was better than in the uncued condition, t(31)=3.23, p<.01, which in turn was better than in the invalid cue condition, t(31)=3.08, p<.01. Table 1 showed subjects' performance in the three

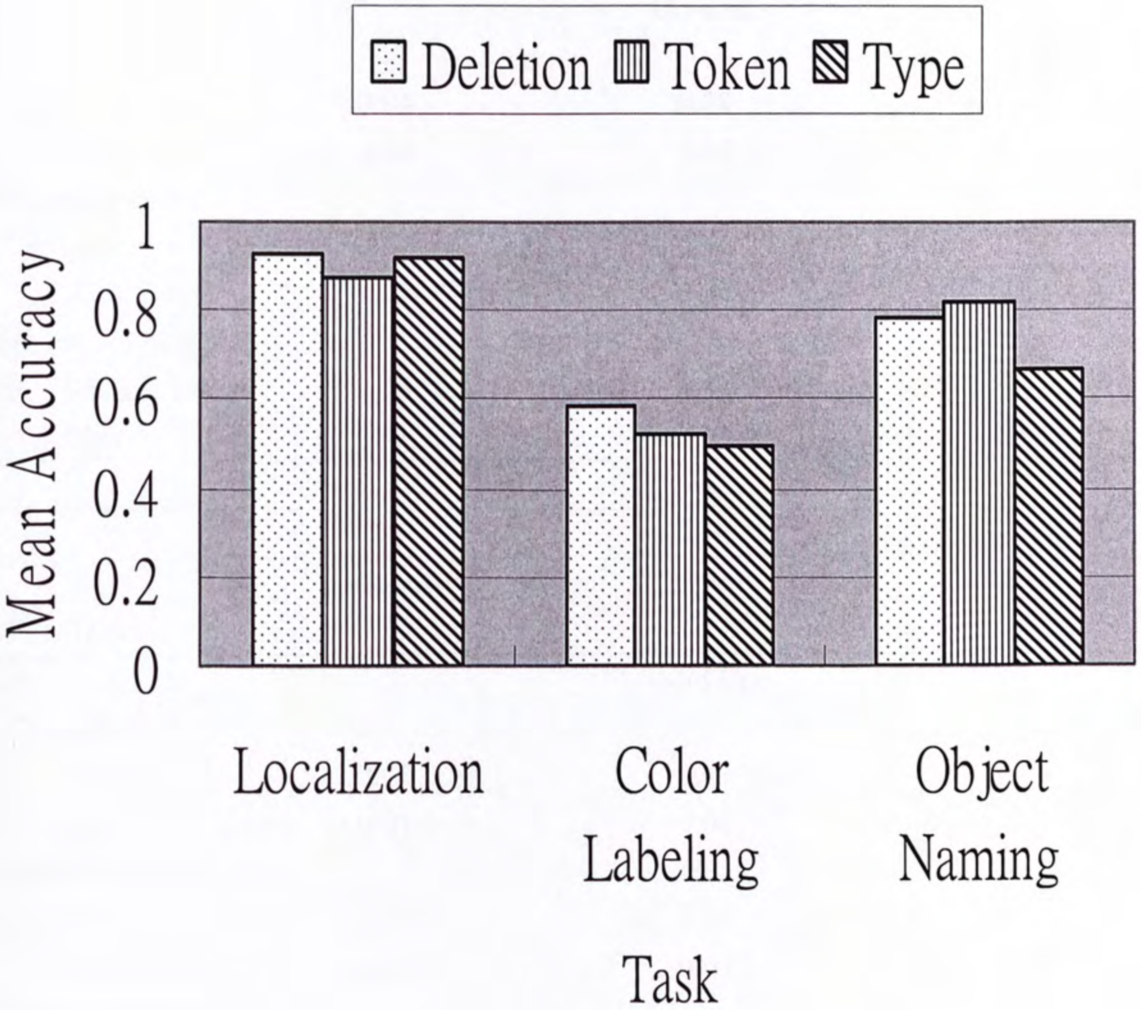

Figure 5. Mean accuracy in different tasks under deletion, token and type change conditions in Experiment 1B.

Task	Change: Deletion	Token	Type
		Un-cued	
Localization			
Mean	0.94	0.88	0.91
S.D.	0.02	0.03	0.02
Color Labeling			
Mean	0.57	0.52	0.47
S.D	0.03	0.04	0.04
Object Naming			
Mean	0.76	0.83	0.72
S.D	0.04	0.03	0.03

Task	Change: Deletion	Token	Type
		Valid Cue	
Localization			
Mean	0.95	0.93	0.98
S.D.	0.01	0.01	0.01
Color Labeling			
Mean	0.67	0.56	0.60
S.D	0.03	0.03	0.03
Object Naming			
Mean	0.84	0.84	0.74
S.D	0.02	0.02	0.03

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Task	Change		
	Deletion	Token	Type
		Invalid Cue	
Localization			
Mean	0.90	0.81	0.88
S.D.	0.03	0.04	0.04
Color Labeling			
Mean	0.52	0.46	0.43
S.D	0.05	0.05	0.04
Object Naming			
Mean	0.75	0.77	0.56
S.D	0.04	0.03	0.04

Table 1. Mean accuracy in each condition in Experiment 1B.

cuing condition in different tasks and changes. Valid cues always produced the best performance and invalid cues always produced the worst performance. Performance also differed in the three tasks, $F(2, 62) = 373.05$, $p < .05$. The performance in the color labeling task was significantly worse than the object naming task, $t(31) = 245.77$, $p < .05$.

Discussion

In this experiment, most results matched with predictions. Cuing helped change detection, which has been observed in many CB studies (e.g. Becker, Pashler, & Anstis, 2000). It indicates that attention was manipulated successfully in the under current paradigm. With the guidance of cue, information within the target region was encoded in a better way than in the uncued conditions which might be in terms of a better stability of the encoded information (Rensink, 2000b), or in terms of a more detailed encoding of visual information. Furthermore, the lack of interaction between cuing and task suggest a homogenous effect of attention across different types of information. In this experiment, participants maintained all three kinds of memory: spatial, semantic and visual details.

Meanwhile, the main effect of task in Experiment 1B showed again that object naming is better performed than color labeling for all cues. The task main effect shows difference in stability of conceptual information and visual details and both are retained. Attentional allocation did not alter this sequence. It suggests that even for the valid cues, both semantic and visual details are encoded, but with differences in stability.

Another difference between Experiment 1A and 1B was found in the main effect of kind of change. Whereas Experiment 1A showed a difference between deletion and token conditions, this time a significant difference was only found between deletion and type conditions. Although the trend was not replicated, it still shows that deletions are easier to detect. Also, in both experiments, difference between token and type change are not significant. It suggests observers are less sensitive towards changes related to visual details and conceptual information than to spatial information. .

Summing up findings related to the processing of the three kinds of information, the result seems inconsistent. When detection rate of localization is used as an indirect index of accessibility of conceptual information and visual details, we do not find differences in detection performance between tokens and types. On the other hand, when participants are asked directly to access to these two kinds of information, there is a difference. Participants are more capable in recalling the name of the target than its visual details. This contradictory result agrees with O'Regan's (2001) idea that, in common CB paradigm, spatial information is usually used in detection but not other visual information. Therefore, implications drawn from previous studies towards semantic information and visual details may be inappropriate.

In line with the above argument, the interaction effect between task and change would further support that argument. From Figure 5, performance of object naming for token change is highest, however, in the other two tasks; participants do not perform best in token trials.

Also performance for type changes is significantly worse than tokens only in the object naming task. This pattern of performance suggests that we process the pre-change and post-change object information separately, so that there could be a kind of interference effect. In type condition, two semantically different objects are presented in the same location, one is in the pre-change scene, and the other is in the post-change scene. In object naming task, the name of the post-change object may interfere with participant's memory. Thus, accuracy dropped. This interference in token change is less, since the semantic category remains the same across pre-change and post-change object. It might be a facilitation effect in object naming task instead, so it would be easier than in type changes. This possibility would not be revealed in typical change detection task.

Comparing experiment 1A and 1B

As mentioned earlier, analysis of data from Experiment 1A and 1B provides ground on understanding effect of allocation of attention in the post-change scene. Also, the main effect of task in two experiments was different and thus an analysis was conducted to compare the effect of experiment directly. The two cuing conditions of experiment 1B were not included because they differed from experiment 1A by an additional factor: cue. Data of the uncued condition in experiment 1B was extracted and compared to data of experiment 1A. A split-plot ANOVA: Experiment * Task * Change was performed. Results showed a significant difference in performance between the two experiments, $F(1, 45) = 29.46$, $p < .05$. The interaction between task * experiment was also significant, $F(2, 90) = 19.82$, $p<.05$. Figure 6 shows the mean accuracy across tasks in two experiments. A simple effect analysis was done. It indicated a significant difference between the experiments in the localization task, $F(1,45)=99.57$, $p<..01$ and in the naming task, $F(1,45)=6.96$, $p<.02$ but not in the color labeling task, $F(1,45)=1.56$, $p>.05$. While the main effect of task was also significant, $F(2, 90) = 148.05$, $p<.05$.

In the separate analysis of each experiment, the main effect of change was significant, but each showed a different pattern. In the combined analysis, the interaction effect between change and experiment was not significant, $F(2, 90)= 1.57$, $p>.05$, and neither the main effect of change, $F(2, 90) = 2.44$, $p>.05$. These suggest that the pattern found in the main effect of change might not be stable. It could be because of the modification brought by the marginally significant interaction between task and change, $F(4, 180) = 2.19$, $p<.08$. The trend, which was same as previous, showed that in object naming task, token change was better than type change but in the localization and color labeling task, the direction was reversed. The three-way interaction, experiment * task * change was non-significant, $F(4, 180) =0.50$, $p>.05$.

Finally, correlation between the "where" and the two "what" tasks to investigate the effect of re-fixation. Table 2 shows the correlations of Experiment 1A and 1B respectively. In Experiment 1A, correlation between localization and color labeling, $r = .68$, $p<.01$;

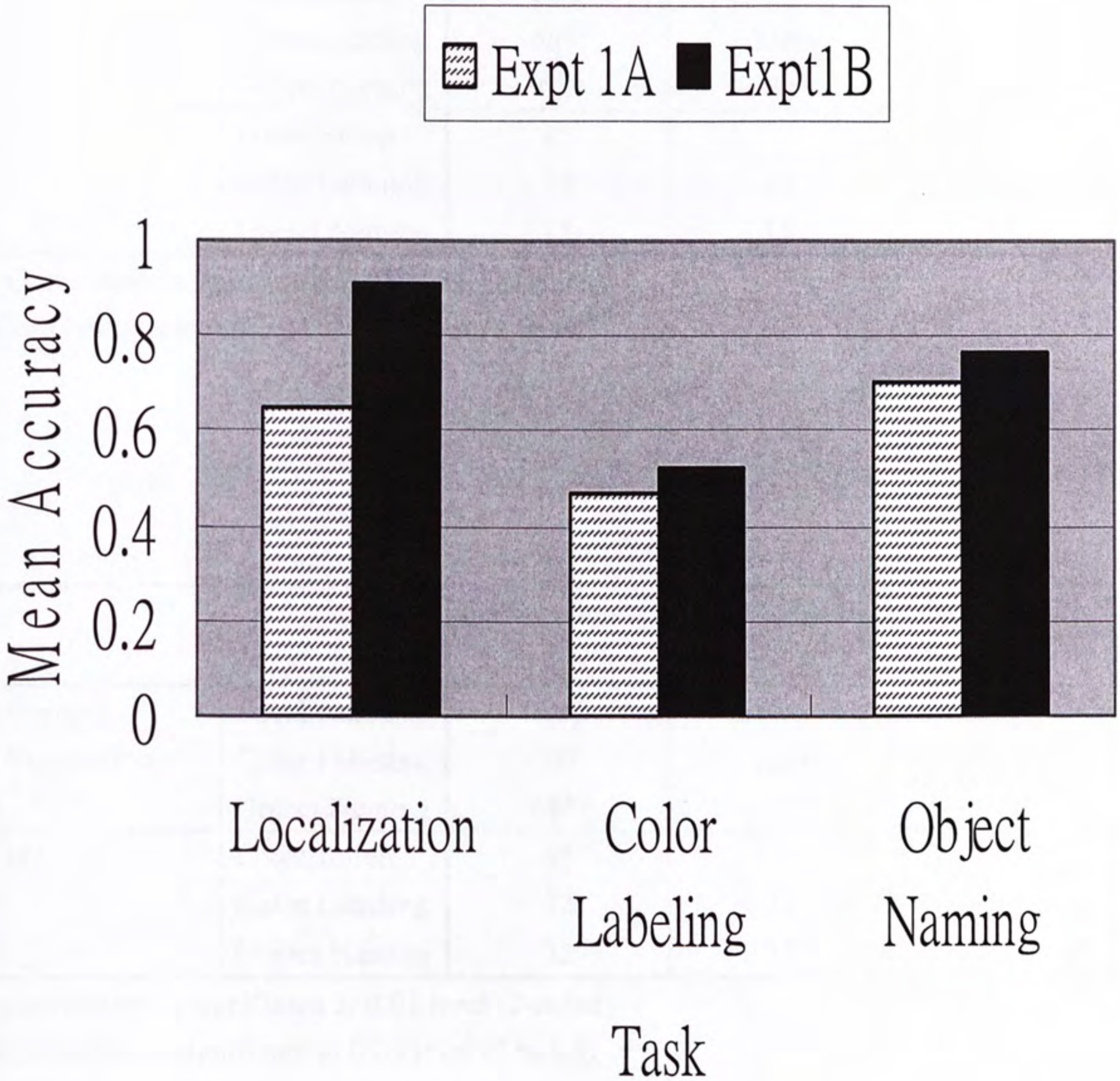

Figure 6. Mean accuracy for Experiment 1A and 1B of different tasks.

		Localization	Color Labeling	Object Naming
Pearson Correlation	Localization	1.00		
	Color Labeling	.68**	1.00	
	Object Naming	.63*	.36	1.00
N	Localization	15		
	Color Labeling	15	15	
	Object Naming	15	15	15

**. Correlation is significant at 0.01 level (2-tailed)

*. Correlation is significant at 0.05 level (2 tailed)

		Localization	Color Labeling	Object Naming
Pearson Correlation	Localization	1.00		
	Color Labeling	.09	1.00	
	Object Naming	.58**	.32	1.00
N	Localization	32		
	Color Labeling	32	32	
	Object Naming	32	32	32

**. Correlation is significant at 0.01 level (2-tailed)

*. Correlation is significant at 0.05 level (2 tailed)

Table2. The upper table shows correlations between performances in different tasks in Experiment 1A. The lower table shows the correlations between performances in different tasks in Experiment 1B.

localization and object naming, $r = .63$, $p<.05$, were significant and moderate, but that between color labeling and object naming was not. Whereas in Experiment 1B, correlation between localization and object naming was significant and moderate, $r = .58$, $p<.01$; but neither the correlation between localization and color labeling, nor between color labeling and object naming was significant.

Discussion

In the localization task, there was a blank screen separating pre-change and post-change scenes in Experiment 1A but not in Experiment 1B. The visual transient brought by scene changes was able to localize the target object in experiment 1B only. Participants performance thus dropped greatly to around 65% in Experiment 1A. This showed that the localization task in normal change detection was closely associated with visual transient detection (Rensink, O'Regan, & Clark, 1997). This result is expected, moreover, performance difference was also found in the object naming but not in the color labeling task across experiments. This may add further insight on the importance of re-fixation. As predicted by Henderson and Hollingworth (2003), allocating attention to the target region in the post-change scene helps retrieval of pre-change information. Nevertheless, they did not mention a difference in the benefit between conceptual information and visual details, which shown here. Incorporating Rensink's coherence theory (2000b) on difference in processing of visual information can help us understand this result. In his theory, processing of scene gist but not visual details could be done without much use of attention. Therefore, in the uncued conditions of both experiments, visual details of the target were not encoded, but conceptual information was encoded. Re-fixation appears to help retrieval of the encoded conceptual information but not the visual details that may be left unencoded.

The second evidence is found in the correlation between performances among the three tasks. In Experiment 1B, accuracy in localization was significantly correlated with that of object naming but not with color labeling This showed that when participant localize the change, they could name the target but they could not recall the color of the target. It supports the claim that the two "what" tasks may involve different kinds of information which affected by attention to different extent. In uncued condition, when participants localize the change with the help of visual transient change, they can recall the name of target but have more difficulties in recalling the color of it. It agrees with Rensink's (2000b) claim that either the encoding of conceptual information would be easier than visual details when focused attention is not used. Or it suggests that the loss of conceptual information in the absence of focused attention is to a smaller extent than visual details, which could incorporate into the visual memory theory.

Finally, the correlation pattern among the three tasks was different in Experiment 1A. Correlation between localization and object naming was significant and also between localization with color labeling. It would suggest that in Experiment 1A, participants usually locate changes when they were attending to the target region just before and after change. Thus, under focused attention, both conceptual information and visual details were encoded. Therefore, a moderate correlation can be found. It highlights the importance of attention in tradition CB studies. If observer is not attending to the target region just before and after the change, detection is difficult (Rensink, O'Regan, & Clark, 1997) and when they are attending, the information is ready for them to pick up (Rensink, 2000b).

Experiment 2

The combined analysis of Experiment 1A and 1B did not show any three-way interaction among experiment, change and task. However, in the separate analysis of each experiment, there were differences between task and change interaction effect. In Experiment 1A, token trials' accuracy in object naming was similar to that of deletion and type but in the localization and color-labeling task, it was lower than the other two kinds of changes. A non-significant task and change interaction was found. In Experiment 1B, in object naming, token changes were most accurately detected. There was a 10% difference between token changes and type changes in accuracy of object naming. In localization, token changes were detected less often than type changes, whereas in color labeling, the two were similar. This is a significant two-way interaction between task and change.

Across two experiments, the same stimuli were used, but the interaction effect was not replicated. It raises the concern that the interaction found in Experiment 1B could be an artifact only. In particular, Experiment 1B did not include any visual disruption. Therefore, Experiment 2 aimed at investigating the task and change interaction further. On one hand, a possible replication of the result would be necessary to ensure the interaction effect can be generalized. On the other hand, in addition to the visual disruption inclusion, another difference between Experiment 1A and 1B also include an additional 500ms temporal gap between pre-change and post-change scenes due to the insertion of a blank screen in Experiment 1A. All these could be a possible candidate for the cause of differences between the two experiments. Thus, in Experiment 2, while trying to replicate result of Experiment 1B, a temporal gap and visual disruption was introduced. A possible replication of the interaction effect with a temporal gap and visual disruption would show that the inconsistent result between previous two experiments maybe caused by some other factors.

Furthermore, the cue was presented after the pre-change scene disappeared instead of during the presentation of the pre-change scene. Landman, Spekreijse and Lamme (2000) suggested that if cuing is effective after disappearance of a pre-change scene, participant's memory of pre-change scene is present. Therefore, if the cue boosted performance in both "what" tasks, it would suggest that both the conceptual information and visual details are available. The presence of conceptual information and visual details is a necessary condition of the visual memory theory (Hollingworth, & Henderson, 2002), since in their theory, the cause of CB is the failure in retrieving the encoded information; if the information is not available in the first place, there is nothing to retrieve.

Method

Participants

16 CUHK students were paid $20 to participate in the 20 minutes experiment.

Materials & apparatus

Materials and setting of computer were the same as Experiment 1A.

Design & Procedure

Similar to Experiment 1A, between pre-change and post-change scene there was a white background scene. On the white background, however, there could be a cue presented. The method of cue presentation was same as Experiment 1B except that this time the cue was shown on the white screen rather than on the photo scene. Another difference in cuing was that there were only valid cue and uncued conditions. Since effect of cue on the interaction was not significant in Experiment 1B and due to the limitation in stimuli, we eliminate the invalid cue condition. The presentation sequence of scenes and blank screen was same as Experiment 1A. Participants saw a fixation "+" (500ms), then a pre-change scene (3000ms) and after that there was a white screen (500ms) with a cross, i.e. the cue shown. Finally, there was a post-change scene (500ms). The design of the three tasks was the same as in previous experiments while kinds of change were reduced to two. Only type and token changes were included, since result from previous experiment suggested that the interaction effect was largely due to differential performance in tasks between type and token change.

Result

Again task was included in the ANOVA, but the main concern is on the interaction effect between task and change. A repeated measures ANOVA was used in a 3(task) * 2(cue) * 2 (change) design. Tasks were again localization, color labeling and object naming. The cuing conditions were: presence of cue and absence of cue. Kinds of change were reduced to two: token and type.

Among all possible interactions, the interactions of task * cue, $F(2, 30) = 19.06$, $p < .05$ and task * change, $F(2, 30) = 113.10$, $p < .05$ were significant. For localization, there was a large difference in performance between the two cuing conditions. The difference between the two cuing conditions was much smaller in the other two tasks. Figure 7 shows the interaction between task and change. In localization and color labeling, participants did better for type changes, but in object naming, they did better for token changes. While, the cue* change interaction, $F(2, 30) = 0.65$, $p > .05$, and the only three-way interaction, task* cue* change, $F(2, 30) = 1.44$, $p > .05$, were non-significant.

The main effects of task and cue were significant, $F(2, 30) = 103.91$, $p < .05$; $F(1, 15) = 55.15$, $p < .05$ respectively. For the main effect of task, pair-wise comparisons were done. In the object naming task subject did worse than in the color labeling task, $t(15) = 9.06$ $p < .01$. Performance in cue present condition was higher than cue absent condition. Lastly, the main

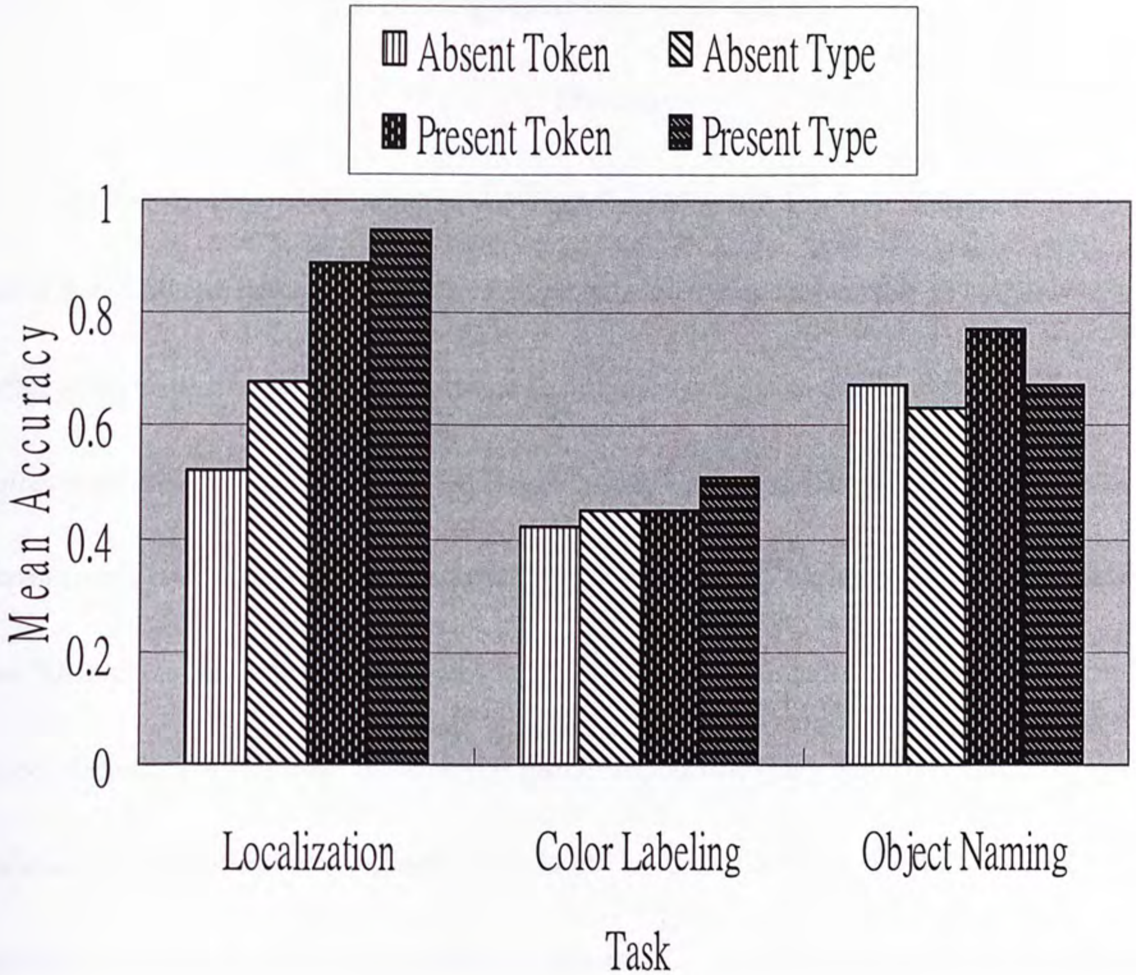

Figure 7. Mean accuracy in all conditions in Experiment 2.

effect of change was marginally significant, $F(1, 15) = 3.46$, $p<0.1$. Performance for type changes gave some indication of being higher than token changes.

Discussion

The main effect of cue replicates findings in Experiment 1B. Participants performed better for valid cue than uncued trials. Participants use the cue effectively in both "what" tasks. It suggests that both the conceptual information and visual details are internally represented even if the scene is erased (Landman, Spekreijse & Lamme, 2000). The better performance in localization for valid cue condition is trivially explained by the fact that the cue informs participants the answer for localization task. Despite that, performance in the color labeling task is always the worst. It further supports that the color-labeling task is more difficult than the object naming task. It could be because of the lack of detailed visual information in scene gist. Visual details are processed at a later time than spatial information (Rensink, 2000b).

The main purpose of this experiment was to replicate result of Experiment 1B, while examining the possible cause of the inconsistent finding between previous experiments. Under a within subject design, the cue absent condition simulated Experiment 1A, in which there was a blank screen displayed between a pre-change and a post-change scene but there was no cue provided throughout the trial. Meanwhile, the valid cue condition simulated Experiment 1B, as there was cue provided during the pre-change scene. The main difference between Experiment 1B and the valid cue condition of Experiment 2 is the blank screen separating the pre-change and post-change scene in the latter experiment. Figure 7 shows the interaction between task and change. This experiment thus shows a highly similar result of Experiment 1B, in that there is a significant interaction between task and change but it is not affected by cuing. Under both cue present and absent conditions, accuracy between type and token changes in object naming and color labeling were consistent. Furthermore, it shows that although the current experiment included a 500ms temporal gap as in Experiment 1A, the interaction effect is found. Therefore, a temporal gap is not the cause of the non-significant interaction between task and change in that Experiment 1A.

To conclude, Experiment 2 provides evidence that the interaction between task and change found in Experiment 1B would be generalized to a paradigm including a visual disruption. This interaction is not affected by attentional allocation, which is manipulated after the disappearance of the pre-change scene.

Experiment 3

In Experiment 2, the interaction action effect between task and change was replicated. This suggests that we obtain separate conceptual information about pre-change and post-change object and that there is interference / facilitation between them. However, a related experiment by Beck and Levin (2003) supports that there is a possibility that the interaction effect is an artifact related to the design of task. In their experiment, the recognition rate of pre-change and post change object were assessed. They showed two sets of object arrays separately. The first one was the pre-change array, which contained several objects. Each object occupied a particular position. One of the objects in the pre-change array was replaced by another unseen object in the post-change array. Following the presentation, participants had to choose the changed object from a display with four objects, two of them were from the pre-change array and two others were new objects. Also they had to choose the replacement from another display with four objects. Again two were selected from the post-change array and two were new objects. The correct recognition rate of the replacement object acted as an index for change detection rate. The recognition rate of changed objects was significantly lower than the replacement object. Therefore, even though the change was noticed, memory for the pre-change object was not stable. Thus, they claimed that we could have a volatile pre-change memory but a good post-change memory. The post-change memory could be beneficial in our object naming task during token trials. In the token change condition, the name of the target and post-change object were the same. Distractors in previous experiments do not discriminate between names of pre-change and post-change objects. Thus, participants could answer correctly if they relied on memory for the post-change object. However, in type trials in which the pre-change and post-change objects were in different semantic category, this strategy would fail. As a result, the extent to which that experiment tested memory for pre-change object was in doubt. It affects the interpretation of the significant interaction effect between task and change. If participants infer the name of pre-change object from the post-change one, for token changes, they would have high accuracy; for type changes, since the names were not the same, their accuracy would be low. It is the exact pattern found in previous experiments.

To solve this problem, Experiment 3 aimed at a closer investigation on the interaction phenomenon. To discriminate participant's pre-change object memory from post-change memory in token trials, color labeling and object naming were combined to form an identification task. Options were all tailor-made for each scene and presented in written form. It included the pre-change object (Target), the post-change object in token trial (Distractor A), the post-change object in type trial (Distractor B), the post-change object in type trial but having incorrect color label (Distractor C) and two other distractors that appeared on that scene. Table 3 showed some examples of options. If participants do not have pre-change object memory, they may make inference from the post-change memory. In token trials, they would choose either Target or Distractor A based on semantic name. Therefore, fewer responses to Distractor A than Target in token trials show that participants can maintain the memory of the pre-change object with its visual details. When considering the type trials, if the same logic can be used, more responses to Target than Distractor B and C would imply that participants know the semantic name of the pre-change object and did not rely on the post-change object. Knowing the name of the pre-change object without knowledge of its

	Target	**Distractor A**	**Distractor B**	**Distractor C**	**Other (1)**	**Other (2)**
Example 1	Blue, tissue pack	Green, tissue pack	Blue, box	Black, box	Black, belt	Green, belt
Example 2	Blue, stapler	Black, stapler	White, clock	Blue, clock	Black, calculator	White, Calculator
Example 3	Red, jar	Orange, jar	Orange, box	White, box	Red, cup	White, cup

Table 3. Example of options in identification task in Experiment 3.

color would lead to confusion between Target and Distractor A. Since, both Target and Distractor A had the same name but differed in the color label. If they cannot retrieve the color of the pre-change object, to decide which one to choose, participants would make a guess which would be correct 50% of times. If, however, they can retrieve the color, selection rate on Target would be higher than on Distractor A in type. It would indicate the memory for visual details for the pre-change object is obtained. Participants knew both the color and name of the pre-change object. In coherence theory, this finding is unlikely in the uncued condition where attention is not allocated to the target region before the change, and those visual details were not kept. Visual memory theory proposed that pre-change object information is maintained in the absence of focused attention. Therefore, response rate for Target in any attentional allocation would be higher than for any other distractor. In terms of accuracy in the identification task, the possible advantage in token condition brought by post-change memory would be minimized, since there were two options having the same object name in both the type and token change conditions.

Method

Participants

24 CUHK students participated in the experiment, and were given $15 for a 15 minutes testing session.

Materials and apparatus

52 sets of photos were chosen from the original 68 sets. Other apparatus and programs used were same as experiment 2.

Design & Procedure

There were four practice trials and 48 testing trials. The experiment was a 2 (cue: cued Vs uncued) by 2 (change: token Vs type) by 2 (task: localization and identification) design. In each condition, there would be 12 test trials. Again like previous experiments, each photo would only be presented once for each participant. Its occurrence in each condition was counter-balanced across participants. The sequence of presentation was randomized.

In terms of cue presentation, scene sequence and duration of each event, all were the same as Experiment 2. The modification made in the current experiment was on the response task. The color labeling and object naming tasks were replaced by identification. Unlike the previous tasks with four options each, there were six options (A to F) in the identification. Each option consisted of a color and a name of object, which were present in the pre-change scene or the post-change scene. Target was the pre-change object. Distractor A was the name of the pre-change object but a color label of the post-change object in token trials, i.e. post-change object in token. Distractor B was the post-change object in type trial. Distractor C was the name of post-change object in type. It differed from Distractor B in the color label. Altogether there were three different object names and three different colors in each option list. All objects and colors were present in the scene. The arrangement of Target and distractors on the option lists was counter-balanced across trials. Participants respond by pressing the number pad with labels A to F.

Before the identification, participants still had to do the localization task. Feedback was given when they responded incorrectly. This was to ensure that in the identification, they localized the target region and could retrieve related information. Again, there were four quadrants. Participants pressed the number pad A to D to indicate their answer. No time limit was given, but they were encouraged to respond as soon as they were able while maintaining accuracy. During the experiment, there was a break given after the 24th testing trial was finished. The experiment lasted not longer than 15 minutes.

Result

A repeated measure ANOVA was used in a 2(task) * 2(cue) * 2 (change) design. Tasks were localization and identification, although the "what" task is changed, performance cannot be compared with localization as well. The cuing conditions were cued (100% valid) and uncued. Kinds of change were token and type.

Among all possible interactions, the interaction of task * change, $F(1, 23) = 5.35$, $p < .05$ and task * cue, $F(1, 23) = 20.36$, $p < .05$ were significant. The task and change interaction reveal that in localization, type changes was better than token changes. This trend reversed in the identification (Figure 8). The main effect of task with $F(1, 23) = 158.30$, $p < .05$ and main effect of cue were significant, $F(1, 23) = 24.80$, $p < .05$. The pattern of task and cue interaction

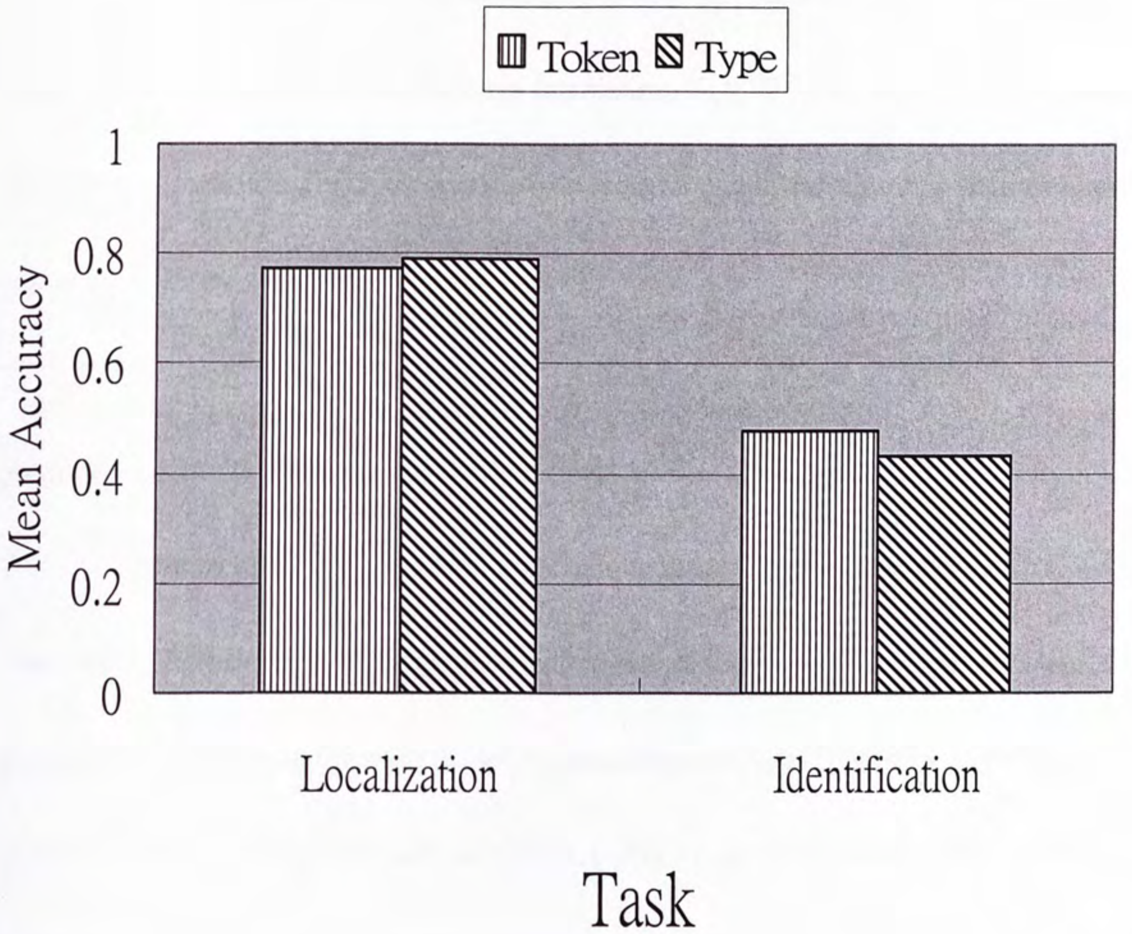

Figure 8. Mean accuracy of token and type change conditions in localization and identification task in experiment 3.

matched with previous results. In accuracy for the localization dropped sharply from the cued to the uncued condition, while the difference in accuracy for the identification was small. The other two-way interaction, cue* change interaction, $F (1, 23) = 1.14$, $p>.05$ and the only three-way interaction, $F (1, 23) = .25$, $p>.05$ were not significant. Table 4 showed mean accuracy in each condition.

The main effect of change was non-significant, $F (1, 23) = 0.33$, $p>.05$, showing that performance in the token change condition was similar to the type change condition.

An analysis of relative selection rates among the target and Distractors A to C was conducted, Table 5 showed the mean selection rate of them. First, a paired t-test was performed selection of Target in the token was compared with Distractor A, for both cue present, $t (23) = 5.92$, $p<.01$, and cue absent, $t (23) = 6.68$, $p<.01$, they were significant. In the type changes, the same analysis was performed, cue present, $t (23) = 7.03$, $p<.01$, cue absent, $t (23) = 8.07$, $p<.01$. Selection rate of Target was higher than that of Distractor A, cuing did not alter this trend. For type changes, selection rate of Target was also significantly higher than Distractor B, $t (23) = 6.50$, $p<.01$ in cue present and in cue absent, $t (23) = 6.17$, $p<.01$ conditions. The same was true in the comparison between Target and Distractor C for type changes. In cue present, $t (23) = 9.00$, $p<.01$; cue absent, $t (23) = 6.46$, $p<.01$.

Lastly, choosing rate of distractor A, B and C (distractors) were compared in repeated measures ANOVA, together with cue and change as two other within subject factors. The

Task	Change: Token	Change: Type
	Cue Absent	
Localization		
Mean	0.67	0.70
S.D.	0.03	0.03
Identification		
Mean	0.46	0.43
S.D	0.03	0.03

Task	Change: Token	Change: Type
	Cue Present	
Localization		
Mean	0.87	0.89
S.D.	0.03	0.03
Identification		
Mean	0.50	0.43
S.D	0.03	0.03

Table 4. Mean accuracy and S.D. in Experiment 3 in each condition.

	Change	
	Token	Type
	Cue absent	
Target		
Mean	.45	.45
S.D.	.12	.16
Distractor A		
Mean	.15	.18
S.D	.09	.11
Distractor B		
Mean	.10	.11
S.D.	.09	.09
Distractor C		
Mean	.12	.13
S.D.	.09	.11

	Change	
	Token	Type
	Cue present	
Target		
Mean	.50	.43
S.D.	.14	.17
Distractor A		
Mean	.22	.15
S.D	.12	.09
Distractor B		
Mean	.06	.14
S.D.	.06	.16
Distractor C		
Mean	.11	.15
S.D.	.09	.10

Table 5 Mean selection rate and S.D. of Target and Distractor A to C in Experiment 3 in each condition.

interaction between distractor and change was significant, $F(2, 46) = 5.47$, $p<.05$. Choosing rate of distractor A was the highest in token conditions, while distractor B had the lowest choosing rate. Choosing rate among three distractors in type conditions was similar. Besides, the main effect of distractor was also significant, $F(2, 46) = 5.61$, $p<.05$. For the remaining effect, all were insignificant, cue, $F(1, 23) = .06$, $p>.05$; change, $F(1, 23) = 2.05$, p>05; distractors* cue, $F(2, 46) = 2.55$, $p>.05$; cue*change, $F(1, 23) = .47$, $p>.05$ and distractor*cue*change, $F(2, 46) = .78$, $p>.05$..

Discussion

Most findings in the experiment were highly consistent with previous experiments. The modification of response requirement of the task did not alter the interaction between task and change. In identification, performance was better for token changes than for type changes. The performance in localization was reversed. Furthermore, paired t-tests showed that selection rates for Target in all conditions were higher than for other options. In terms of the token condition, this result indicates that participants can make use of the pre-change object memory. Participants did not use the visual details of post-change object to determine the target. Since in type change trials, they can discriminate Target from Distractor A as well. In type, higher selection rate of Target than Distractor A further indicates a possibility that they can maintain the visual details. Also, throughout a series of paired t-tests, comparison between Target and other options were consistent in the cue present and absent conditions.

Taken together, these results suggest that in both the cue present and cue absent conditions, we have pre-change scene memory.

Experiment 4

In Experiment 1 and 2, distractors in the object naming may not appear in the scene. They may be inconsistent with the meaning of the scene. Thus, participants correctly identify the target through an elimination of any inconsistent objects. For the color labeling task, to get a correct answer, elimination may not be a good strategy. The distractor colors are more likely to appear in the scene, and are unlikely to be inconsistent with the general meaning. Due to the design of tasks, participants could get the correct answer from elimination in object naming task only. This result, however, is not related to the stability of different kinds of information.

Another possible strategy in these experiments would be verbalization. By using verbalization, participants could remember the objects present in the scene by actively labeling them. During the pre-change presentation, they could name objects and their color found in the scene without paying attention to other object properties. Afterwards, they would perform the localization task. The encoding of the post-change scene could be skipped. Since they know that if they were making error in the localization task, they would receive feedback. Maintaining memory of objects present in the pre-change scene would help them perform the identification task when they know the correct target region. In this way, they may simply give in the localization task and take the feedback as a hint. Although, across trials there would be great amount of highly similar information verbally encoded which would be susceptible to great interference, verbalization is still a possible strategy. It would lead participants view the pre-change scene as if they were memorizing it but would not require them to compare information across scenes.

According to O'Regan (1992), the external world serves as our outside memory. We actually do not encode much visual information when we are looking around. A similar idea was also found in a study by Triesch, *et. al.* (2003). They asked participants to perform a motor decision making task. There were two slots where participants had to move the objects into one of them. Sometimes, the size of the objects will affect participants' decision on where they should put the object in. Sometimes it did not. During the task, in some trial, the size of one of the objects was changed while in other trials, a property irrelevant to the task was changed. They found that change on task relevant properties were detected more frequently than irrelevant one; suggesting that we extract information from the environment when the information is relevant to our task. These ideas suggest that under normal situation, we would not attend to all information present; we are more sensitive to task relevant information. Thus, the use of any memorization strategy should be avoided in CB studies.

The problem with the use of a memorization strategy not only related to causing a condition different from normal viewing, it also causes differences in task performance which could explain the inconsistent findings of the stability conceptual information and visual details. In localization, the two kinds of information were represented by the type and token changes. The differences in localization task between the two changes were non-significant. In the two "what" tasks, each represented a kind of information, object naming was better performed than color labeling. Therefore, in Experiment 4, the use of memorization strategies was discouraged. Therefore, in Experiment 4 participants were instructed that the post-change scene would appear again after the localization task. They would have time to view it as additional information for the identification task, so that this could discourage them from using any memorization strategy. Also, it could further reduced participants' tendency in choosing the post-change object during identification task.

Furthermore, Experiment 4 also served as a further test on the stability of pre-change information. Henderson and Hollingworth (2003) suggested that a post-change scene would be a strong retrieval cue for encoded information. Its presence would boost up performance in identification task, as re-fixation could take place. This would be against the finding by Landman, Spekreijse, and Lamme, (2003), who found that a cue present after the post-change scene was not effective. The ineffectiveness of a cue present after the post-change scene would be consistent with Rensink's idea that the pre-change scene information was lost. In the comparison between Experiment 1A and 1B, the re-fixation during the initial appearance of the post-change scene was found to improve performance for the object naming task but not the color labeling task. Thus, in Experiment 4, it took the investigation one step forward, to the extent that whether re-fixation would be useful after the post-change scene was shown for the second time, after the change detection process.

Method

Participants

16 CUHK students participated and were given $20 after completion.

Materials & apparatus

The 52 sets of photos in Experiment 3 were used. The experiment was controlled by a program that was written by Microsoft Visual Basic 6.0 running in a PC. Two Gateway 17 inch monitors were connected with the computer. The resolution of each monitor was in 640 * 480 pixels, running at 75Hz. Apart from the number pad, all keys on the keyboard were inactivated during the experiment.

Design & Procedure

It was a two (task: localization and identification) * two (change: token and type) * two (post-change scene: presence Vs absence) repeated-measures design. Most of the procedures were similar to Experiment 3, except three aspects. First, there was no cue provided on the blank screen between pre-change scene and post-change scene, though a red cross was on the blank screen. Second, participants were instructed that photos were always presented in monitor 1, which they sat in front of. After they had done the localization task, options for the identification task would be shown on monitor 2, which was placed next to monitor 1, to ensure that participants could see both monitors easily. Participants knew that sometimes in the identification task, the post-change scene would be shown on monitor 1 as well, but sometimes it was only a blank screen. They would only know if the post-change scene was present when the options were shown. They were given seven seconds to complete each task. To ensure they can read all options in identification, they were advised to read options first before referring to the post-change scene if it was shown.

Result

A repeated-measures ANOVA was performed and the same analysis principle was used as Experiment 1A. Among the main effects, presence of post-change scene did not make a difference, $F(1, 15) = 0.26$, $p>.05$. Similarly, kind of change was not significant, $F(1, 15) = 0.26$, $p>.05$. Only the main effect of task was significant, $F(1, 15) = 195.58$, $p<.05$. Performance for localization was much higher than that for identification. There was a significant task * change interaction, $F(1, 15) = 6.05$, $p<.05$. Figure 9 showed that as in other experiments, performance in type trials was better than token trials for localization, but the trend was reversed in identification. All other effects did not reach statistical significance. They include: task * presence of post-change scene, $F(1, 15) = 1.48$, $p>.05$; presence of post-change scene * change $F(1, 15) = 2.56$, $p>.05$; and the three-way interaction, $F(1, 15) = 0.78$, $p>.05$. Table 6 showed the mean accuracy in each condition. In addition, paired t-tests

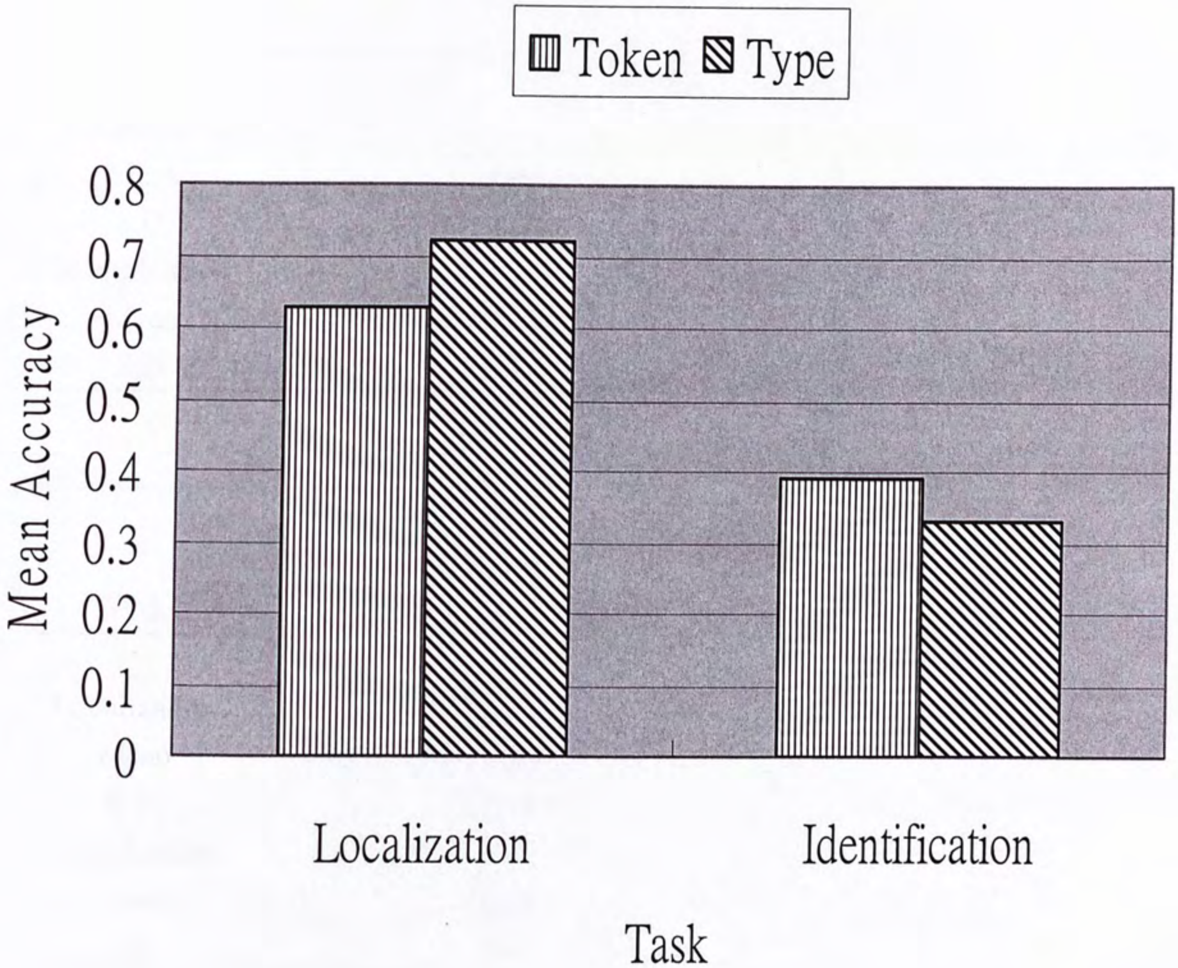

Figure 9. Mean accuracy in type and token changes for localization and identification task in Experiment 4.

Task	Change: Token	Change: Type
	Post-change scene absent	
Localization		
Mean	0.61	0.69
S.D.	0.04	0.05
Identification		
Mean	0.42	0.32
S.D	0.04	0.03

Task	Change: Token	Change: Type
	Post-change scene present	
Localization		
Mean	0.66	0.74
S.D.	0.04	0.04
Identification		
Mean	0.36	0.35
S.D	0.04	0.03

Table 6. Mean accuracy in each condition in Experiment 4.

	Change	
	Token	Type
	Post-change scene absent	
Target		
Mean	.36	.35
S.D.	.18	.12
Distractor A		
Mean	.05	.08
S.D	.06	.09
Distractor B		
Mean	.13	.12
S.D.	.11	.09
Distractor C		
Mean	.05	.08
S.D.	.07	.08

	Change	
	Token	Type
	Post-change scene present	
Target		
Mean	.42	.32
S.D.	.16	.13
Distractor A		
Mean	.06	.09
S.D	.10	.07
Distractor B		
Mean	.10	.10
S.D.	.06	.07
Distractor C		
Mean	.06	.06
S.D.	.09	.08

Table 7. Mean selection rate of Target and Distractor A to C in Experiment 4.

compared selection rates of response category were again performed. Highly similar to Experiment 3, for token trials, the selection rates of Target was higher than that of Distractor A, both when the post-change scene was present, $t(15) = 6.55$, $p<.01$, and when the post-change scene was absent $t(15) = 7.01$, $p<.01$. The same was true for type trials, when the post-change scene was present, $t\ (15) = 5.07$, $p<.01$, and when it was absent, $t\ (15) = 6.08$, $p<.01$. In the comparison between selection rates of Target and Distractor B in type trials, again result was not affect by the presence of post-change scene; when the post-change scene was present, $t(15) = 6.62$, $p<.01$,and when it was absent, $t(15) = 6.64$, $p<.01$. Lastly, comparing selection rates of Target and Distractor C in the type conditions, when the post-change scene was present, $t\ (15) = 5.77$, $p<.01$, and when it is absent, $t\ (15) = 9.71$, $p<.01$. Selection rates of Target and Distractor A to C in all conditions were shown in Table 7.

Similar to Experiment 3, choosing rate of the three distractors were included in repeated measure ANOVA together with two within subject factors: post-change scene presence and change. Among all effects, only the main effect of distractor was significant, $F(2, 14) = 8.61$, $p<.05$. Distractor B was more frequently chosen than distractor A, $F(1, 15) = 9.27$, $p<.01$ and C, $F(1,15) = 16.61$, $p<.01$, while the choosing rate of distractor C was the lowest but it did not significantly different from the choosing rate of distractor A, $F(1, 15) = .22$, $p>.05$. Others, post-change scene presence, $F(1, 15) = .59$, $p>.05$; change $F(1, 15) = 2.38$, $p>.05$; distractors * post-change scene presence, $F(2, 30) = .48$, $p>.05$; distractor *change $F(2, 30) = .76$,

$p > .05$; post-change scene presence * change $F(1, 15) = .05$, $p > .05$ and the only three way interaction, $F(2, 30) = .25$, $p > .05$, were all insignificant.

Discussion

In general, the findings in this experiment were very consistent with the result of Experiment 3. There was a main effect of task and an interaction between task and change, while the main effect of change was lacking. If there is effect of the presence of post-change scene, it would only affect the performance of the identification task, since it was presented after the localization. However, it did not produce any significant effect. This shows that identification performance across two post-change scene conditions do not differ. On the other hand, cuing effects of the post-change scene may be shadowed by the cuing effects of feedback from the localization task. They both give spatial cues for the identification of the target. Therefore, the difference between post-change scene present and absent appeared to be small. Lastly, it could also represent participants' inability in using the post-change scene as the reference. This could be related to the duration given to participants in encoding the scene and the possible time constraint given when they were doing the identification task.

General Discussion

Theories derived from CB studies describe visual processing of different kinds of information: spatial, conceptual and visual details. Rensink (2000b) in his coherence theory states that we cannot hold much information of previously attended objects once attention shifts. On the other hand, Hollingworth and Henderson (2002) in their visual memory theory claim the opposite. Information is kept in the long-term visual memory even after attention shifts. In spite of the disagreement, the traditional CB task actually does not test conceptual information and visual details directly (O'Regan, 2001). He believes that this information should be tested in "what" tasks, which assess participants' memory of the object. The traditional task, which requires participants to respond when they see the change, is a "where" task (localization task) only. It does not require participants to have a memory of the object but just to have a sense of knowing that there is a change. Therefore, results obtained from CB studies may not have a direct implication for the memory of "what' information. This may be a cause of the dispute between the two major CB theories.

Attention and CB

In this thesis, participants have preformed both the "where" task and the "what" tasks. A "where" task asks participants to locate the target region (1 out of 4) and "what" tasks include an object naming question and a color-labeling question in Experiments 1 and 2, and an identification question in Experiments 3 and 4. Results obtained from the "where" task agrees with previous CB studies findings. In Experiment 1, we show that visual disruption strongly affects participants change detection performance. In Experiment 1B, the obtained accuracy is 90% when no visual disruption occurs. This contrasts with the high miss rate (40%) in experiments having a blank screen between scenes, supporting a close linkage between visual transients caused by a change and detection of change. As suggested by Rensink, O'Regan, & Clark (1997), they argue that a specific region in which a visual transient occurs would draw attention, and thus a change could be detected. With visual disruption, detection of a visual transient in a specific region is blocked. As a result, change blindness is observed.

The involvement of "what" task may guide participant's attention to the name and color of the object, it may boost up detection rate and trigger participant's use of detection strategy that they only pay attention to certain specific object properties. This strategy is less likely to be triggered spontaneously in other change blindness studies, in which a more general task was given. Yet, their primary task (localization) is to detect the change which is not specified and is same as Rensink's and Hollingworth's task. Result showed that performance in localization is not close to 100%.

To investigate the effect of attention during encoding, attentional allocation before the change occurred was manipulated in Experiment 1B. Without visual disruption, attention located the change immediately after it occurred. Thus, attentional allocation of post-change scene is at the target region. Performance in the valid cue condition was higher than in the invalid cue condition for localization, demonstrating that the effect of a local visual transient is affected by cuing in the pre-change scene (an exogenous cue). It also highlights the importance of attentional allocation before the change. Attention, which is paid to the target region just before the change, helps change detection in situations with and without visual disruption.

The importance of attentional allocation in the pre-change scene is shown not only in "where" tasks, but also in the "what" tasks. In Experiment 1B, in both "what" tasks, performance in the valid cue condition is better than in the invalid cue condition. Participants are more accurate in choosing the name and color of the target object when they had paid attention just before and after the change than the condition where they only had paid attention after the change. This result suggests that more information is retained with attention. Also, better performance in uncued trials than invalid trials could supports Henderson and Hollingworth (2003) criticism towards the control of attentional allocation in Rensink's experiments. In the uncued conditions, attentional allocation was not monitored. In some trials, focused attention was paid at non-target region, thus gave a low accuracy; while in other trials attention was paid at target region, giving a better performance. Since the result in the uncued condition is average across all trials, the overall performance is produced by trials which focused attention was paid at target region and trials which focused attention was paid at non-target region. This result was intermediate between the valid cue condition (that focused attention was paid at target region in all trials) and the invalid cue condition (that focused attention was paid at non-target region in all trials). The uncued conditions, therefore, would simulate situation that the control over attention allocation is loose, as in the traditional flicker experiment. Result produced might under-estimate the influence of attention for change detection where attention is allocated on the target region.

A result opposing the coherence theory (Rensink, 2000b) comes from the interaction effect between task and experiment when comparing Experiment 1A and 1B. Under the current experimental paradigm, a visual transient changes hinder greatly participants' performance in localization. Its effect on the object naming and color labeling is much smaller. This not only showed a separation between "where" and "what" tasks (O'Regan, 2001), but also shows that participant's memory for conceptual and visual details is maintained even there is a visual disruption, supporting the visual memory theory (Hollingworth, & Henderson, 2002). Due to the design of experiment, "what" tasks always follow the "where" task and participants get feedback when they make a localization error. This procedure provides spatial information for the retrieval of "what" information, which helps retrieval of the encoded information, as suggested by Hollingworth and Henderson. It may lead to an over-estimated stability of the "what" information, especially when compared with situation that there is no spatial information given to participants, and they have to recall the name and color of the pre-change object directly, i.e. the traditional CB studies. Nevertheless, the result shows that retrieval of "what" information is at least possible and is over 50%. Furthermore, it contradicts with coherence theory (2000b) which predicts a loss of information when the target is not under focused attention.

In the cue absent condition of Experiment 2, accuracy of color labeling and object naming is around 50%. Also, the percentage of correct identifications in Experiments 3 and 4 are also around 50%. These results are convergent evidence showing that participants keep the conceptual and visual details of attended object. Experiments which participants are given 3s for pre-change scene viewing show that participants' memory of target is relatively good.

To close the discussion over the two opposing theories in stability of encoded information, the above findings illustrate that there should be a better distinction between traditional memory tasks with change blindness tasks. Change blindness is a striking phenomenon due to its high missing rate (Simons & Levin, 1997). Participants often miss 70% of the change in traditional paradigm. These findings are usually obtained in experiments with very brief presentation time. Contrasting with this claim, a study reported by Henderson and Hollingworth (2003) found a detection rate was as high as 90%. The great difference among detection rates partly comes from the difference in the nature of tasks. It is also due to difference in time provided to participants during pre-change scene encoding. Our presentation duration is intermediate between two camps, and coincidentally, our detection rate found is also intermediate between the two. This could reflect the possible influence on encoding duration in change detection rate. A prolonged presentation of the pre-change scene in laboratory setting would probably encourage participants to use an intentional memorization strategy. This not only would greatly damage the external validity of the change blindness experiment, but also affect the conclusion arrived in relation to information stability.

Stability of different kinds of visual information

In Experiment 1B, there was a main effect of cue which did not interact with kinds of task. In this experiment, there was no visual disruption and the cue was shown during the presentation of the pre-change scene. Cue was found to be effective in all the three tasks, localization, object naming and color labeling. The result contrasts with the effect of cue in Experiment 2, in which cue was shown after the pre-change scene. Again, there were three tasks. Besides a significant main effect of cue, a significant cue and task interaction effect was found. Cue helped participants in the localization task to a much greater extent than the object naming and the color labeling task. It suggests that cue shown after the encoding of pre-change scene seems offer little help in "what" tasks. The same phenomenon was found in Experiment 3, although the "what" task was changed to an identification task. There was a significant cue and task interaction; little differences between performance for cue present and cue absent conditions for the identification but differences for localization. Lastly, in Experiment 4, the re-presentation of the post-change scene did not boost up participants' performance in the identification. All these showed that cue presented after the encoding of pre-change scene did not improve "what" tasks performance, though it improved the performance for the "where" task.

Furthermore, Landman, Spekreijse and Lamme (2000) provide a finding related to the argument that ineffectiveness of cue would demonstrate a lost of information. In their study, they used a typical localization task and they showed that the effectiveness of the cue varies across its presentation time. In general, the cue is effective when it is presented before the post-change scene. Its effectiveness decreases as temporal gap between its presentation and pre-change scene increases. Result found in this thesis would therefore suggest that retrieval of the name and color of pre-change is more difficult due to greater information loss than spatial information. There would be a separation between the encoded spatial information and other abstract information, as suggested by Hollingworth and Henderson (2002).

The suggestion that spatial information is specially encoded is further strengthen by the finding related to the kinds of change, which is highly consistent across experiments and previous studies (e.g. Keane, Hayward, & Burke, 2003; Favelle, Hayward, Burke, & Palmisano, in press). In both Experiment 1A and 1B, better performance in the detection of deletion than other kinds of changes is obtained. The superior performance shows that our visual system is more sensitive to changes in spatial layout. It agrees with coherence theory (Rensink, 2000b) and visual memory theory (Hollingworth & Henderson, 2002) that in visual information processing, spatial layout information is processed specifically.

Regarding the difference in relative stability between conceptual information and visual details, which coherence theory and visual memory theory hold different view, insight can be found as well. In coherence theory, Rensink (2000b) tends to stress the image-like format of visual details. Visual properties are maintained in System I for on-time processing and are more readily lost than conceptual information. In visual memory theory, Hollingworth and Henderson (2002) explicitly suggested that the visual details are stored in an abstract form. In Experiments 1 and 2, conceptual information is assessed by the object naming task and visual details are assessed by the color labeling task. Differences in performance are consistently found, the object naming task is better performed than the color labeling task and this appears to reflect difference in their relative stability.

Another result suggesting a difference between the two kinds of information is the interaction effect between task and experiment, when pooling the data of uncued trials in Experiment 1A and 1B. In Experiment 1B, without visual disruption, participants can quickly look at the target region. The target may be re-fixated. This re-fixation boosts performance of object naming but not color labeling, implying a greater loss of visual details than conceptual information while attention is not maintained. Therefore, once attention travels back, retrieval is less efficient.

Nevertheless, the same conclusion cannot be arrived when an indirect index is used. In the experiments, type of change is always included as a within-subjects factor. There is no significant difference between type and token changes for localization. To explain this inconsistence, hint may be discovered from the interaction effect between task and change in Experiment 1 and 2. Performance for token changes is better than for type changes in the object naming task but not in the color labeling task. This result could be because of the repetition in the processing of semantic information in token trials. This repetition is not found in color labeling. For token and type changes, different color labels are processed across pre-change and post-change scenes. The interaction may be an experimental artifact. Our modification of "what" task in terms of an identification task in Experiments 3 and 4 was designed to address this issue, and suggests the opposite. Participants can discriminate the target from the post-change scene object in both token and type conditions. Selection rate of targets is always the highest. This would suggest that observers did not confuse the name of pre-change and post-change object; they remembered the name of pre-change object as well as its color.

If observers can retrieve both the conceptual and the visual details of the pre-change object, a similar accuracy in the localization task across the type and token changes may show that differences between pre-change and post-change scene do not determine observers' change detection sensitivity. In the type changes, there are changes for conceptual information and for visual details, while in token changes, only visual details are changed. In spite of the difference in the changed information, performance in the localization task was similar between two kinds of change in experiments. The ease of change detection process does not work like the analogy that when there are two differences between scenes, it is easier to find the change than when there is only one difference between scenes. It may reveal that in the comparison process between the pre-change and the post-change scenes in CB task, factors other than the memory component are involved. This would agree with findings in comparison blindness (e.g. Scott-Brown, Baker, & Orbach, 2000), which is highly similar to CB, but the two versions of scene are present simultaneously.

In short, across the three kinds of information, spatial information would be the most stable, and visual details would be the least stable, while conceptual information is intermediate.

Conclusion

Evidence supporting visual memory theory (Hollingworth, & Henderson, 2002) is found. It suggests that we can maintain a certain amount of pre-change scene information regardless of attentional allocation. This could be generalized in situations that a reasonable amount of time is given for scene processing. Situations in which observers fail doing a change detection task in flicker paradigm that do not show a high retention rate of information could be related to the short presentation time of the pre-change scene and the disrupted scene presentation process.

Concerning the stability of different kinds of visual information, the differential effectiveness of a cue present after the pre--change scene towards "what" tasks and "where" task, shows that non-spatial information is more readily lost than spatial information, as suggested in coherence theory (Rensink, 2000b). However, it is probably stored in an abstract format as well, supporting Hollingworth and Henderson (2002) claim for LTM object file. Since, re-fixation of post-change scene boosts performance in object naming task. Also, the overall performance in color labeling task is still around 50%. To conclude, results in this thesis shows evidence for preserved representation which can be retrieved. In additional, it shows that the preserved representation is in an abstract form. Since in the experiments, object names and the color of the object is presented in a written form rather than an visual image which was used in previous studies.

In addition, the experiment included three separate tasks, demonstrating there is a need to separate "where" and "what" tasks, in order to draw a comprehensive conclusion on visual processing. The traditional CB paradigm may actually ask participants to implicitly perform a "where" task, but due to the lack of visual transient change in change region; participants are actually forced to carry out a "what" task instead. With an extremely limited presentation duration, "what" information may not be processed thoroughly to an abstract level and cannot be retrieved. As a result change blindness is observed and lead to the conclusion that the encoded information is lost easily.

All these show that we do represent visual information but change blindness is still observed. It provides insight on real world application. Sometimes, it is necessary for us to notice a change in current situation (e.g. driving in a familiar environment). If these are change in the environment (e.g. a road block) , and we are not aware of it because we are not actively comparing the current scene with information we had. We would have to draw people's attention to the change, as well as find out way to let people initiate the comparison process (Simons, & Ambinder, 2005).

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